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Inventory and Statistical Characterization of Inorganic Soil Constituents in Illinois

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16. Abstract

This report presents a statistical analysis of the Regulated Substances Library (RSL) developed by the Illinois Department of Transportation. The RSL is comprised of surficial soil chemistry data obtained from rights-of-way subsurface soil sampling conducted for routine preliminary site investigations. The 3.7-million-record RSL database is compared with four independent studies of inorganic soil constituents of naturally occurring soils in Illinois. A selection of 22 inorganic soil analytes are examined in this study: Al, Sb, As, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Ni, K, Se, Na, Tl, V, and Zn. RSL database summary statistics, mean, median, minimum, maximum, 5th percentile, and 95th percentile, are determined for Illinois counties and for recognized environmental concern, non-recognized environmental concern, and de minimis site contamination classifications. The RSL database at a 95% confidence level is compared with current and proposed thresholds for defining naturally occurring soil concentrations for the selected analytes. The revised thresholds proposed by Cahill in 2017 are predominantly larger than the current standards found in the Tiered Approach to Corrective Action Objectives rules and are in better agreement with observed distributions of soil concentrations for both naturally occurring and RSL soils. A notable exception is antimony (Sb), for which Cahill proposed a reduced threshold similar in magnitude to the median for many Illinois Department of Transportation districts.

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EXECUTIVE SUMMARY

This report presents a statistical analysis of the Regulated Substances Library (RSL) developed by the Illinois Department of Transportation (IDOT). The RSL is comprised of surficial soil chemistry data obtained from rights-of-way (ROW) sampling conducted for routine preliminary site investigations in preparation for potential road construction activities. The RSL data were derived from the sampling of subsurface materials to characterize the site conditions encountered. They may be composed of natural soils, disturbed soils, or placed materials and may contain elevated concentrations of soil analytes if anthropogenic contamination is present. The report is a statistical analysis of RSL data and, as such, makes no determination as to the validity of the RSL as a source of natural background soil data. Were RSL data to be applied as the natural background, additional supporting justification would need to be provided, the source of which is beyond the scope of this report. The RSL database was downloaded to create a local static copy on January 16, 2020. All statistics contained in this report were generated from the RSL database state corresponding to this time stamp. The RSL database is compared with four independent studies of inorganic soil constituents of naturally occurring soils in Illinois. These studies include those from the Illinois State Geological Survey by Dreher and Follmer in five reports from 2004 to 2005, and separately by Follmer and Zhang in three reports from 2002 to 2003, from the United States Geological Survey by Smith and collaborators in 2013, and by the Illinois Environmental Protection Agency (IEPA) Office of Chemical Safety in 1994. These studies are summarized and analyzed in a 2017 compendium study by Cahill titled "Inorganic Chemical Composition of Illinois Soils" published by the Illinois State Geological Survey (ISGS) as Circular 590. A selection of 22 soil analytes are examined in the present study: aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), calcium (Ca), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), mercury (Hg), nickel (Ni), potassium (K), selenium (Se), sodium (Na), thallium (Tl), vanadium (V), and zinc (Zn). Summary statistics, mean, median, minimum, maximum, 5th percentile, and 95th percentile, are determined for the RSL database for Illinois counties and for recognized environmental concern, non-recognized environmental concern, and de minimis site contamination categories. The RSL database at a 95% confidence level is compared with current standards defined by the 1994 IEPA Tiered Approach to Corrective Action Objectives (TACO) standards and proposed thresholds suggested in Circular 590 for defining naturally occurring soil concentrations for the selected analytes. The revised thresholds proposed in Circular 590 are predominantly larger than the current standards found in TACO standards and are more closely aligned with the observed distributions of soil concentration in this evaluation for both naturally occurring and RSL soils. A notable exception is antimony, for which Circular 590 proposed a reduced threshold similar in magnitude to the median for many IDOT districts.

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CHAPTER 1: INTRODUCTION

The Illinois State Geological Survey (ISGS) examines soil chemistry data for soils obtained from routine rights-of-way preliminary site investigations conducted by the Illinois Department of Transportation (IDOT) in preparation for potential road construction activities. The IDOT Regulated Substances Library (RSL) is an extensive soil chemistry database comprising 15 years of environmental consulting data. Analyses in this report are limited to a statistical review of data obtained from the RSL and their comparison with selected thresholds and standards. Several priority soil constituents are selected for detailed analysis and are identified as those that commonly exceed current Clean Construction and Demolition Debris (CCDD) regulations for uncontaminated soils during road construction projects.

Priority constituents are included in the list of 22 inorganic analytes examined in this study: Al, Sb, As, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Ni, K, Se, Na, Tl, V, and Zn. These constituents can occur naturally in Illinois soils; however, elevated concentrations may be encountered because of anthropogenic contamination. Current natural background concentration levels of soil constituents, as determined by the Illinois Environmental Protection Agency (IEPA) Office of Chemical Safety in 1994, applied a 50th percentile confidence level (median) to the data set of 275 data points, representing all 102 Illinois counties (IEPA, 1994). The current standard specifies separate values for a metropolitan statistical area (MSA) and non-MSA counties: General, Section 742.APPENDIX A General, Section 742, Table G of the Tiered Approach to Corrective Action Objectives (TACO) rules. MSA counties are denoted with a dotted hatch pattern on choropleth maps found in the appendices (Anderson & Yacucci, 2021a). The RSL data were also compared with the 2019 IEPA-proposed revised standard for background concentration levels established at the 95th percentile confidence level for naturally occurring soils in Illinois. The 2019 IEPA-proposed revisions to this standard are based on previous studies of Illinois natural soils conducted by the United States Geological Survey (USGS) (Smith et al., 2013) and ISGS (Dreher & Follmer, 2004a, 2004b, 2004c, 2004d, 2005; Dreher, Follmer, & Zhang, 2002, 2003a, 2003b). The aforementioned studies and those conducted by Zhang and Frost (2002a, 2002b) are compiled and reviewed in an ISGS compendium on the inorganic chemical composition of Illinois soils, which includes 1,272 samples (Cahill, 2017).

The results of this RSL study present the range of inorganic constituent concentrations with respect to the IDOT site contamination categories such as recognized environmental concern (REC), non-REC, and de minimis (site contamination is present but not a threat to human health or environment) and for various spatial subsets (IDOT geographic region, IDOT geographic district, and county). A direct comparison between RSL results and the naturally occurring soil concentrations determined by Cahill (2017) was made using the 95th percentile confidence level. In the absence of a detailed site-by-site analysis accounting for former site use with identified potential pollution point sources, it was not possible to determine whether the concentration for a given inorganic soil analyte obtained from the RSL was due to naturally occurring soil conditions or soil contamination. Therefore, to determine definitively whether an RSL sample represented the natural background concentration with respect to any or all soil analytes of interest, additional site-specific analysis is required. This additional analysis is beyond the scope of this report and is not performed as part of this analysis. Despite this shortcoming, the RSL contains approximately 3.7 million records and therefore represents a significant potential resource in the analysis and evaluation of inorganic constituents of Illinois soils.

DUE-DILIGENCE TERMS

For the purpose of this report, the following terms are defined as they apply to IDOT projects:

Recognized environmental concern: Where REC(s) were indicated in the preliminary environmental site assessment (PESA) document as present, a condition was noted that may be indicative of releases or potential releases of hazardous substances on, at, in, or adjoining the site. The indication of a REC being present on a site does not signify that contaminants are present.

De minimis: For the purposes of this report, the following were considered de minimis conditions:

- Normal use of lead-based paint on exteriors and interiors of buildings and structures.
- Use of asbestos-containing materials in building construction.
- Transformers in normal use (unless they were observed to be leaking) that appear on an environmental regulatory list or were otherwise determined to pose a hazard not related to normal use.
- Agricultural use of pesticides and herbicides. In addition, most land in Illinois was under agricultural use prior to its conversion to residential, industrial, or commercial development. Pesticides, both regulated and otherwise, may have been used throughout the project area at any time. Unless specifically discussed elsewhere in this report, no information regarding past pesticide use that would be subject to enforcement action was located for this project; thus, such use is considered a de minimis condition.

Non-recognized environmental concern: A non-REC site would be a site with no RECs or de minimis conditions according to the above descriptions. The ISGS does not have formal definitions of these terms in the preliminary environmental site assessment or the PESA manual, and they use the American Society for Testing and Materials (ASTM) definitions as a baseline for their work.

SOIL DEVELOPMENT

In this report, we applied the definition of a natural soil defined by the Natural Resources Conservation Service, which was also applied in Cahill (2017):

> *Soil* . . . is a natural body comprised of solids (minerals and organic matter), liquid, and gases that occurs on the land surface, occupies space, and is characterized by one or both of the following: horizons, or layers, that are distinguishable from the initial material as a result of additions, losses, transfers, and transformations of energy and matter *or* the ability to support rooted plants in a natural environment. . . . The upper limit of soil is the boundary between soil and air, shallow water, live plants, or plant materials that have not begun to decompose. Areas are not considered to have soil if the surface is permanently covered by water too deep (typically more than 2.5 m) for the growth of rooted plants. . . . The lower boundary that separates soil from the non-soil underneath is most difficult to define. Soil consists of the horizons near the earth's

> surface that, in contrast to the underlying parent material, have been altered by the interactions of climate, relief, and living organisms over time. Commonly, soil grades at its lower boundary to hard rock or to earthy materials virtually devoid of animals, roots, or other marks of biological activity. . . . For purposes of classification, the lower boundary of soil is arbitrarily set at 200 cm. (Soil Survey Staff, 1999, 9)

The majority of parent material for Illinois soils is related to the history of glaciation of the state, which occurred during six or more glaciations covering three episodes: the pre-Illinois, Illinois, and Wisconsin Episodes (Johnson, Moore, & McKay, 1986; Barnhardt, 2010). Over the course of glaciation, ice sheets originating in Canada entered Illinois from the northwest, northeast, and east. Parent material from this activity, including the interglacial periods, consists of loess, till, and outwash. The remainder of the soils are derived predominantly from floodplain alluvium and bedrock. Near-surface soils often act as a pollution sink, and, according to Cahill (2017, 1), "near urban industrial areas, around mining operations, and along highways, soils often absorb by-products with heavy metals, including As, Ba, Cd, Cr, Cu, Hg, Ni, Pb, and Zn."

ILLINOIS SOIL CHEMISTRY RESOURCES

Early studies of the geochemical properties of Illinois soils published beginning in 1960 examined the composition of Illinois tills and loess (Beavers, 1960; Wascher et al., 1960; Wascher et al., 1971), weathering indicators (Beavers et al., 1963), and selected trace elements that occurred statewide (Omueta & Jones, 1977; Jones, 1986, 1989; Jones 2002). The first statewide analysis examining a comprehensive suite of soil analytes (45) was initiated by the ISGS in 1992 (Zhang & Frost, 2002). The recently published ISGS Circular 590 (Cahill, 2017) is a compendium of previous studies of natural soils. The data set was compiled from three studies: Dreher and Follmer (compiled from 1998 to 2003), Zhang and Frost (compiled from 2002 to 2005), and Smith et al. (compiled from 2004 to 2007). It contains 1,272 soil chemistry data points collected from across the state, representing all 102 Illinois counties.

To examine the potential of statewide patterns and trends in soil analytes, Zhang and Frost (2002) made an extensive investigation of inorganic soil constituents. They examined "elemental distributions as functions of the Peoria Silt [loess] thinning pattern" and concluded that "no significant trends seem to exist" (2002, 1). Peoria Silt is the dominant parent material of Illinois soils, with all silts composed of "loess (63%), outwash (8%), till (12%), and alluvium (12%)" (Fehrenbacher et al., 1984, as cited in Zhang & Frost, 2002, 5). The parent material of a soil is "the most important factor controlling the chemical composition of a soil" (Zhang & Frost, 2002, 5). Alluding to the lack of evidence found in previous studies of Illinois soils constituents, Cahill (2017, 1) stated, "No attempt was made to discuss geochemical associations of the elements or to plot the results to establish regional trends." Similarly, the statistical analysis of the IDOT RSL database did not seek to establish regional trends based on soil series or regional patterns.

CHAPTER 2: IDOT-REGULATED SUBSTANCES LIBRARY—DEVELOPMENT AND ANALYSIS

Statistical analyses were performed in Python from a CSV (comma-separated values) table export of the Regulated Substances Library (RSL), an ArcGIS spatial database designed and developed by IDOT and hosted on the Illinois Department of Innovation & Technology (DoIT) infrastructure. The table structure, data fields, and quality assurance/quality control methods for the spatial database were developed by IDOT, DoIT, and ISGS staff. Data from the preliminary site investigations (PSI) program were submitted by the contracted statewide consulting companies that completed the PSI. Chemical and physical analyses were conducted at contract laboratories approved by IDOT and accredited by the National Environmental Laboratory Accreditation Conference. Specific chemical and physical analyses were conducted in accordance with U.S. Environmental Protection Agency SW-846, Third Edition or American Society for Testing and Materials procedures (US EPA 1997). These data were submitted to QA/QC by IDOT and uploaded into the spatial database. The ISGS downloaded the “dot_gis_ICT_ANALYSIS” and “dot_gis_ICT_PROJECTSTATIONSAMPLE” tables for statistical analysis of the joined tables in Python. To ensure a constant and repeatable statistical analysis, the RSL database was downloaded to create a local static copy on January 16, 2020 (Anderson & Yacucci, 2021b). All statistics contained in this report were generated from the RSL database state corresponding to this time stamp.

DATABASE ANALYSIS: PYTHON SCRIPTING FOR PREPROCESSING, STATISTICAL ANALYSIS, AND MAP GENERATION

The RSL database was compiled from more than 15 years of IDOT environmental site investigations, and the associated soil analyses were performed by environmental testing laboratories. The RSL database contains spatial information for each boring location at which soil sampling and the associated analysis were performed and the predominant project county. Because of the large spatial extents of linear transportation infrastructure projects, the borings pertaining to a given project could cross county borders. Therefore, a new database field was defined to include the county in which each boring in the database was located. All mapped data presented in this report are in State Plane (NAD83/Illinois East [US feet], EPSG:3435). To generate this county field, a spatial join was performed following the projection of the GeoDataFrames for both the boring locations and shapefile (defining Illinois county polygons) to State Plane in Python. This calculation was performed by using the Python libraries “GeoPandas” and “shapely.” In addition to these libraries, “matplotlib” and “Descartes” were used to plot and format the map data generated from the Python statistical analysis. A general data analysis was performed in Python by using “pandas” for data ingestion and management. A statistical analysis was performed by using “NumPy” from the “SciPy” libraries.

STATISTICAL ANALYSIS METHODS

Statistical distributions of soil concentrations were calculated for 22 analytes with respect to IDOT site contamination categories (REC, non-REC, and de minimis) and for various spatial subsets (IDOT region, IDOT district, and county, see Figure 1). Analyte soil concentrations were visualized as both histograms and boxplots plots. The magnitudes of natural background concentrations for soil constituents are defined in Cahill (2017) at a 95% confidence level.

The 95% confidence level was defined in this study as the 95th percentile of a ranked list of RSL soil concentration data for a given analyte. This approach did not assume a data distribution, and specifically, it did not assume the data were normality distributed. The 95% confidence level was uniformly applied to the analysis of all analytes in the RSL database to provide consistency with the findings of Cahill (2017). Although not assumed in this study, normality tests can be applied (e.g., a Shapiro–Wilk, Anderson–Darling, or Kolmogorov–Smirnov test) to determine the degree to which a normal distribution fits the given population of interest. The 95th percentile was calculated in this report by using the "NumPy" Python library and the percentile function. The 95% confidence level is labeled on all histogram plots as "*95th percentile*" and shown with a black dashed line.

Current natural background concentration levels of soil constituents, as determined by the Illinois Environmental Protection Agency (IEPA) Office of Chemical Safety in 1994, applied a 50th percentile confidence level (median) to the data set of 275 data points, representing all 102 Illinois counties (IEPA, 1994). The current standard specifies separate values for metropolitan statistical area (MSA) and non-MSA counties: General, Section 742 APPENDIX A and General, Section 742 Table G of the Tiered Approach to Corrective Action Objectives (TACO) rules (Figure 2). MSA counties are denoted with a dotted hatch pattern on all choropleth maps found in this report and the appendices (Anderson & Yacucci, 2021a). The current background concentration levels on all figures in the main report and appendices are labeled as "*Background Curr*" and shown with a red dotted line on both histograms and boxplots.

The RSL data were also compared with the 2019 IEPA-proposed revised standard for background concentration levels established at the 95th percentile confidence level for naturally occurring soils in Illinois. The 2019 IEPA-proposed revisions to this standard are based on previous studies of Illinois natural soils conducted by the United States Geological Survey (USGS) (Smith et al., 2013) and ISGS (Dreher & Follmer, 2004a, 2004b, 2004c, 2004d, 2005; Dreher, Follmer, & Zhang, 2002, 2003a, 2003b). The aforementioned studies and those conducted by Zhang and Frost (2002a, 2002b) are compiled and reviewed in an ISGS compendium on the inorganic chemical composition of Illinois soils, which includes 1,272 samples (Cahill, 2017). The proposed concentration levels on all figures in this report and the appendices (Anderson & Yacucci, 2021a) are labeled as "*Background New*" and shown with a green dotted line on both histograms and boxplots.

The plotting conventions applied to boxplots are shown in Figure 3, indicating the statistical quartiles and 95% confidence interval on the median. Note, the mean is not shown on boxplots presented in this analysis, as shown in Figure 3. The 95% confidence interval of the median is provided on all boxplots and is shown by an indented notch (see Figure 3). The confidence interval notch may extend beyond the interquartile range (IQR) for distributions with a greater uncertainty. The notch assists in making visual comparisons of distributions as there is a strong likelihood that medians of the respective distributions are statistically different if the corresponding notches around the median do not overlap (Chambers et al., 1983). To clarify, the 95% confidence level discussed in reference to RSL database evaluation is not to be confused with the 95% confidence interval (defined range), as is commonly presented in association with a mean or median value.

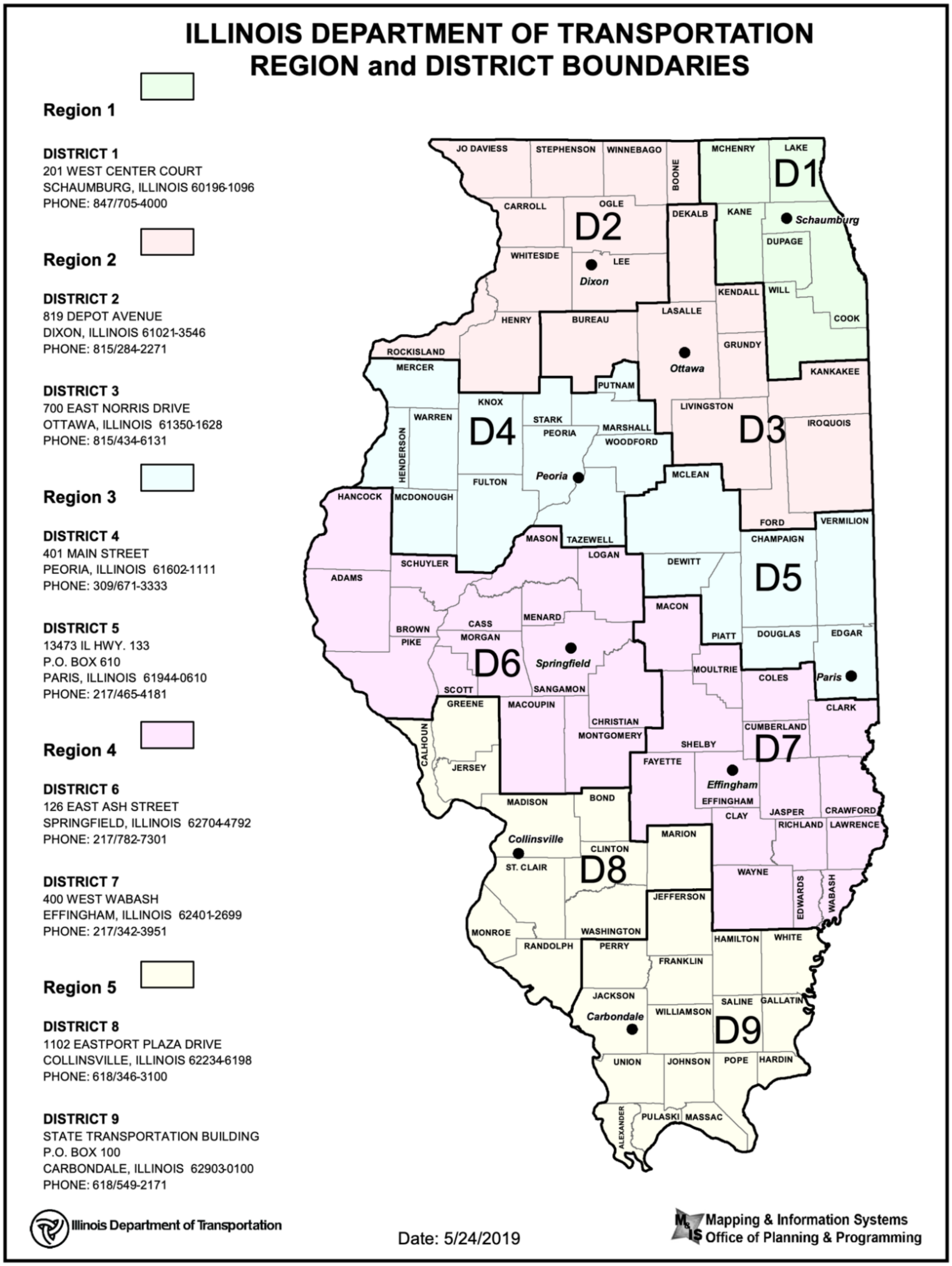

Figure 1. Map. IDOT region and district map.

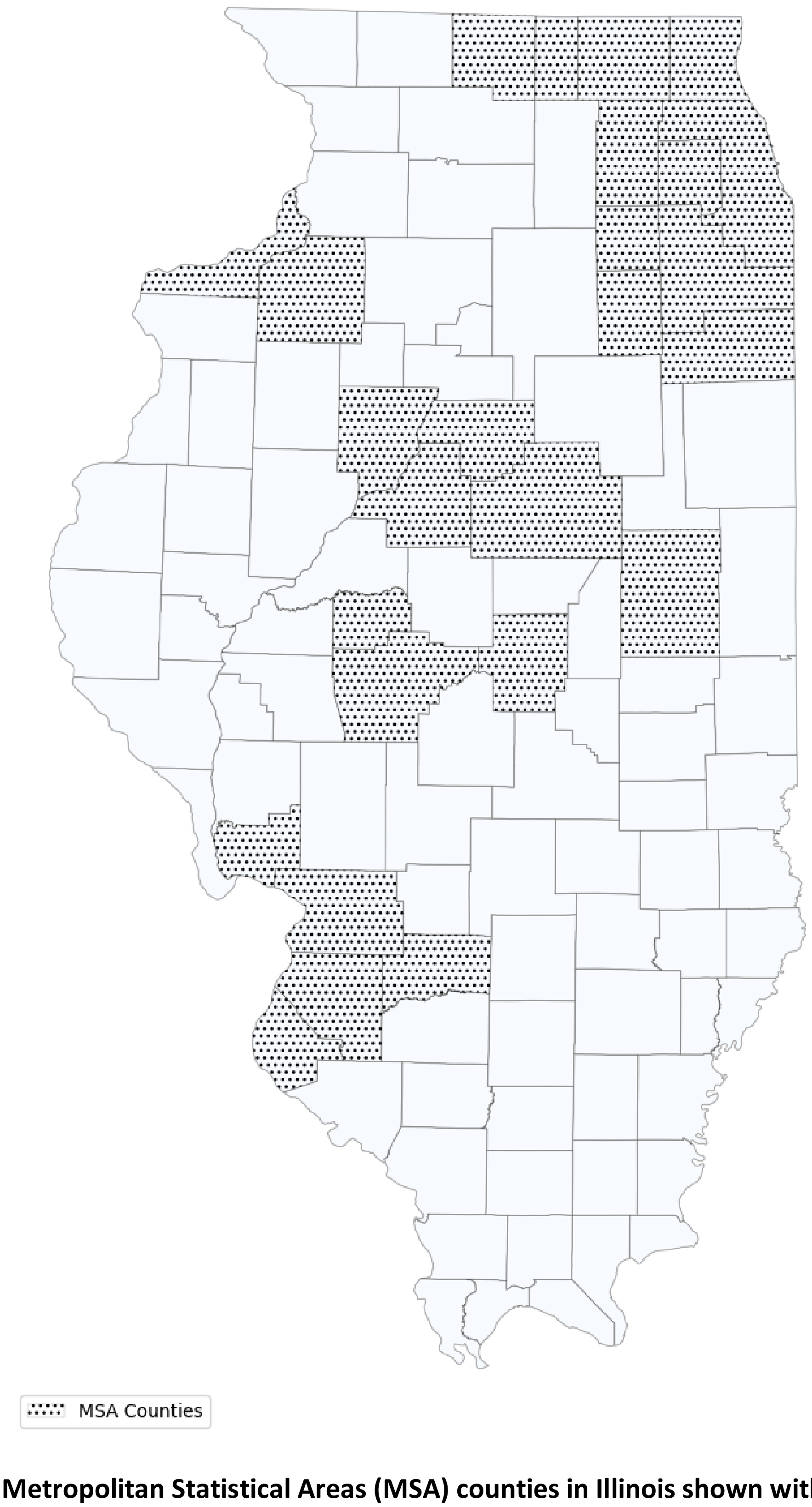

Figure 2. Map. Metropolitan Statistical Areas (MSA) counties in Illinois shown with dotted hatching. All choropleth maps in this report and the appendices (Anderson & Yacucci, 2021a) apply dotted hatching to indicate MSA counties.

A common threshold for potential outlier detection is the product of 1.5 and the IQR, as first proposed by Tukey (1977) to define “inner fences.” The IQR is defined as the difference between the third quartile (Q3 = 75th percentile) and the first quartile (Q1 = 25th percentile). In all boxplots presented in this study, the extent of the whiskers is defined as 1.5 × IQR (the Tukey fence), and the points present beyond these limits are labeled as potential outliers and represented as open circles. The selection of this threshold has become an accepted method of potential outlier detection because it identifies potential outliers as those beyond 2.698 standard deviations, resulting in approximately 0.7% of data points being labeled as potential outliers (<1%) for a normal distribution (see Figure 4). Note, that this convention for labeling potential outliers is applied only for purposes of visualization. Further analysis is required to confirm a potential outlier as an outlier datapoint. For data distributions with highly skewed data (e.g., strong positive skewness, as observed in several analytes), the percentage of data points labeled as potential outliers will vary from those stated previously for a normal distribution.

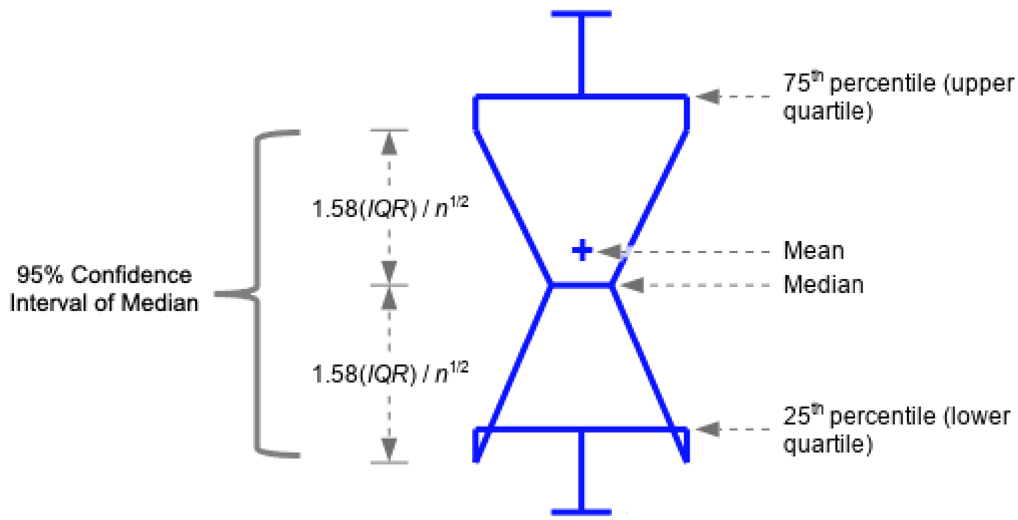

Figure 3. Diagram of the 95% confidence interval of the median, as shown by the notch. Figure 3 is modified from SAS® 9.4 Graph Template Language, Copyright © 2016, SAS Institute Inc., USA. All Rights Reserved. Reproduced with permission of SAS Institute Inc, Cary, NC.

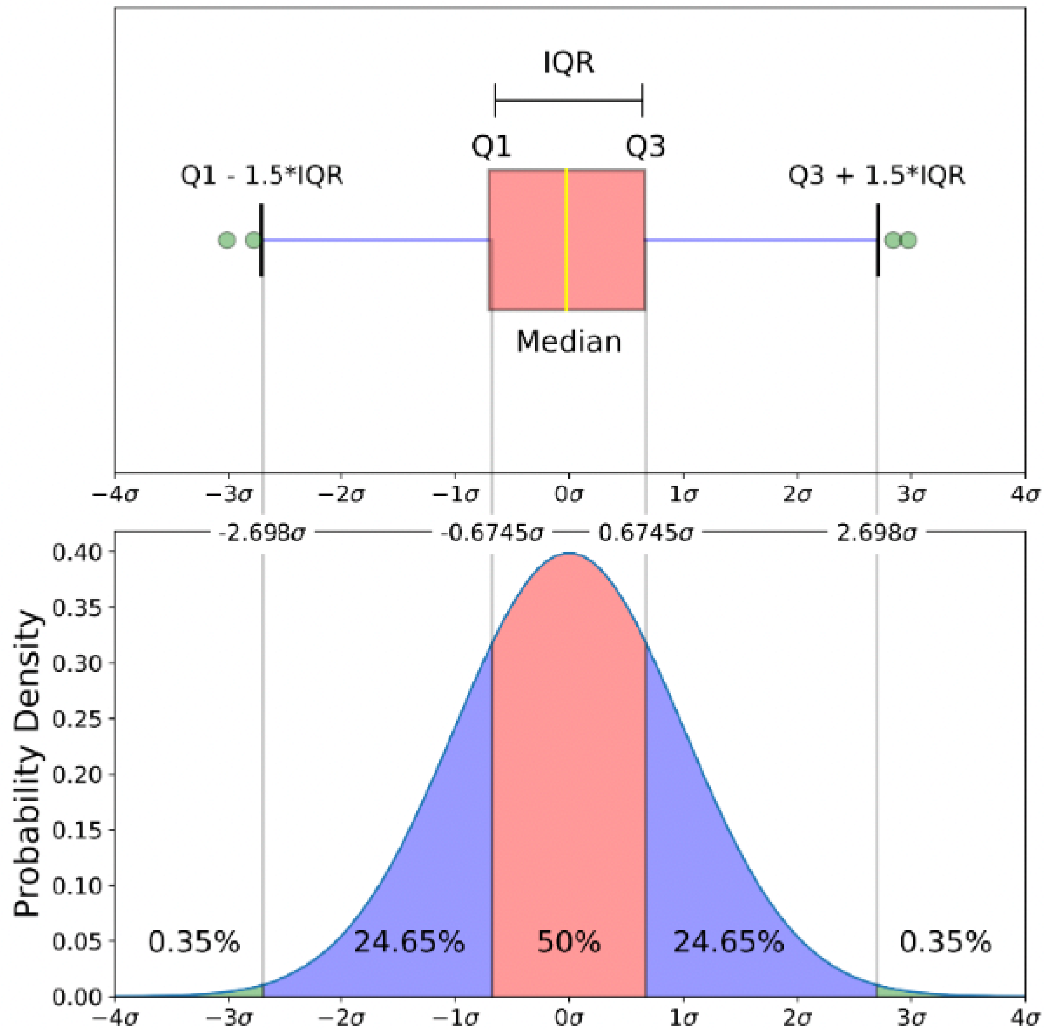

Figure 4. Boxplot diagram of a nearly normal distribution compared with the probability density function for a normal distribution. IQR is interquartile range, Q1 is first quartile, and Q3 is third quartile. From Galarnyk (2018). Used with permission of the author.

CHAPTER 3: RESULTS

The IDOT Regulated Substances Library (RSL) database contains soil chemistry data for soils obtained from preliminary site investigations (PSIs) conducted in IDOT rights-of-way (ROW) for proposed road construction activities. Soil sampling is performed to meet PSI testing requirements and to characterize existing site conditions. Consequently, soil descriptions, metadata, and sampling techniques differ from those conducted for the characterization of natural soils. The RSL soils are not differentiated by soil horizon or soil series and will contain soil contamination if present. Soil sampling is performed at discrete intervals from the surface to depths typically up to 10 ft. The depth(s) from which soil samples were chosen for analysis at any given soil boring sampling location was determined mainly based on the corresponding depth of the planned road construction activity. The RSL data classify current land use as residential or industrial as well as within a site contamination category (REC, non-REC, de minimis); however, the data provide no description of the natural land cover that may or may not be present. Soil samples in the RSL are included in the analysis independently of whether they are naturally occurring or composed of placed materials.

ANALYSIS OF SELECTED INORGANIC SOIL CONSTITUENTS

This analysis reviews the findings from four independent studies of inorganic soil constituent concentrations in natural soils in Illinois and discussed in the compendium study by Cahill (2017). Sampling of natural soils was performed by soil horizon, but methods varied across studies. Dreher and Follmer (2002–2005) obtained samples by soil subhorizons for all major horizons (A–E). Zhang and Frost (2002) combined multiple depth samples to develop a composite A horizon and a composite B horizon. Smith et al. (2013) provided soil data for the surface, a composite A horizon, and a composite C horizon, and in an IEPA study (1994, Table 1) sampling occurred at variable depths (Cahill, 2017). Table 1 presents a statistical comparison of these studies with RSL data for selected inorganic soil constituents: Al, Sb, As, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Hg, Ni, K, Se, Na, Tl, V, and Zn. The natural soils data in Table 1 and Table 2 are provided for A horizon, which is defined as (1) the Dreher and Follmer (2002–2005) A horizon, (2) the 0.1 to 0.2 m depth interval of Zhang and Frost, (3) the 0.0 to 0.2 m depth interval of Smith et al. (2013), and (4) the interval shown in Table 1 of IEPA (1994) (Cahill, 2017). The RSL data provided in Table 1 and Table 2 are not representative of near-surface concentrations (i.e., A horizon equivalent) but are instead a composite of all sampling depths (0 to 3.05 m [0 to 10 ft]). In the RSL, data are provided for elemental analytes (mg/kg = ppm) and are converted to metal oxide weight percentages as required to enable comparison with the natural background studies in Table 1. In Table 2, natural background concentrations of selected inorganic constituents are statistically compared with RSL 95% confidence levels for the site contamination categories (REC, non-REC, de minimis). By reviewing the statistical analyses in Table 1 and Table 2, we could determine the deviation of RSL concentrations of inorganic soil constituents from natural background concentrations. Detailed histograms of RSL data are provided for state and IDOT region, IDOT district, and county spatial subsets in the appendices to examine the spatial variability and its relationship to thresholds defining natural background concentrations (Anderson & Yacucci, 2021a).

Table 1. Comparison of Four Natural Background Concentration Studies (A horizon) with IDOT RSL (All Depths) for Select Inorganic Soil Constituents[1,2]

Constituent	Unit	Mean	Median	Minimum	Maximum	n > DT*	5th percentile	95th percentile
Aluminum oxide (Al_2O_3)								
Zhang & Frost (ISGS)[†]	%	9.55	9.51	0.38	17.03	90	7.45	11.64
Dreher & Follmer (ISGS)[§]	%	9.51	9.6	3.6	14.8	137	6.76	12.79
Smith et al. (USGS)[‡]	%	8.17	8.3	4	12.01	88	5.47	10.22
IEPA (1994, Table 1)[¦]	%	1.93	1.75	0.26	7.03	213		
RSL - REC (IDOT)[¤]	%	1.74	1.78	0.00	5.86	3,462	0.42	3.02
RSL - non-REC (IDOT)[††]	%	1.69	1.78	0.55	3.02	65	0.65	2.65
RSL - de minimis (IDOT)[§§]	%	1.81	1.87	0.00014	4.53	1,310	0.57	2.83
Calcium oxide (CaO)								
Zhang & Frost (ISGS)[†]	%	0.93	0.73	0.11	4.59	90	0.33	2.78
Dreher & Follmer (ISGS)[§]	%	1.3	0.92	0.18	12.11	137	0.43	3.01
Smith et al. (USGS)[‡]	%	1.31	0.93	0.22	9.27	88	0.46	3.93
IEPA (1994, Table 1)[¦]	%	2.31	0.89	0.09	27.74	213		
RSL - REC (IDOT)[¤]	%	6.44	4.90	0.000001	58.77	14,408	0.27	18.19
RSL - non-REC (IDOT)[††]	%	7.05	6.30	0.05	27.98	602	0.22	17.89
RSL - de minimis (IDOT)[§§]	%	7.10	5.88	0.001	47.57	5,218	0.38	18.19
Iron oxide (Fe_2O_3)								
Zhang & Frost (ISGS)[†]	%	3.38	3.29	1.06	7.87	90	2.16	5.11
Dreher & Follmer (ISGS)[§]	%	3.25	3.19	1.22	6.1	137	1.9	4.74
Smith et al. (USGS)[‡]	%	2.88	2.79	1.1	12.1	88	1.64	4
IEPA (1994, Table 1)[¦]	%	2.31	2.17	0.47	11.44			
RSL - REC (IDOT)[¤]	%	5.41	5.44	0.0000017	60.75	16,904	1.66	8.99
RSL - non-REC (IDOT)[††]	%	4.82	4.81	0.83	17.14	610	1.79	8.01
RSL - de minimis (IDOT)[§§]	%	5.24	5.44	0.00048	47.96	5,231	2.03	8.31
Magnesium oxide (MgO)								
Zhang & Frost (ISGS)[†]	%	0.85	0.71	0.2	3.13	90	0.39	2.08
Dreher & Follmer (ISGS)[§]	%	0.83	0.76	0.07	3.8	137	0.28	1.73
Smith et al. (USGS)[‡]	%	0.81	0.65	0.3	3.6	88	0.33	2.14
IEPA (1994, Table 1)[¦]	%	1.19	0.56	0.08	12.35			
RSL - REC (IDOT)[¤]	%	3.47	2.82	0.000001	71.31	16,231	0.27	10.28
RSL - non-REC (IDOT)[††]	%	4.14	3.81	0.06	21.56	610	0.20	11.44
RSL - de minimis (IDOT)[§§]	%	4.31	3.81	0.0008	36.48	5,231	0.53	11.44

	Unit	Mean	Median	Minimum	Maximum	n > DT*	5th percentile	95th percentile
Manganese oxide (MnO)								
Zhang & Frost (ISGS)[†]	%	0.12	0.12	0.03	0.3	90	0.06	0.2
Dreher & Follmer (ISGS)[§]	%	0.13	0.11	0.02	0.5	137	0.04	0.26
Smith et al. (USGS)[‡]	%	0.11	0.1	0.002	0.3	88	0.04	0.19
IEPA (1994, Table 1)[¦]	%	0.09	0.07	0.01	0.7	244		
RSL - REC (IDOT)[¤]	%	0.06	0.05	0.000001	2.69	16,906	0.02	0.13
RSL - non-REC (IDOT)[††]	%	0.06	0.05	0.0043	0.96	610	0.02	0.11
RSL - de minimis (IDOT)[§§]	%	0.06	0.05	0.0001	1.29	5,231	0.02	0.11
Potassium oxide (K_2O)								
Zhang & Frost (ISGS)[†]	%	2.12	2.12	1.24	3.98	90	1.57	2.77
Dreher & Follmer (ISGS)[§]	%	2.01	2.01	1.11	2.95	137	1.46	2.66
Smith et al. (USGS)[‡]	%	192	1.93	0.84	2.6	88	1.38	2.34
IEPA (1994, Table 1)[¦]	%	0.16	0.13	0.03	0.7	240		
RSL - REC (IDOT)[¤]	%	0.18	0.16	0.000001	1.72	9,093	0.04	0.37
RSL - non-REC (IDOT)[††]	%	0.16	0.13	0.02	0.82	421	0.04	0.33
RSL - de minimis (IDOT)[§§]	%	0.18	0.16	0.000002	0.78	3,723	0.05	0.37
Sodium oxide (Na_2O)								
Zhang & Frost (ISGS)[†]	%	0.98	0.98	0.58	1.63	90	0.67	1.32
Dreher & Follmer (ISGS)[§]	%	0.89	0.9	0.45	1.23	137	0.58	1.19
Smith et al. (USGS)[‡]	%	0.89	0.89	0.35	1.4	88	0.62	1.15
IEPA (1994, Table 1)[¦]	%	0.03	0.02	0.01	1.02	205		
RSL - REC (IDOT)[¤]	%	0.09	0.06	0.000001	3.77	14,394	0.01	0.28
RSL - non-REC (IDOT)[††]	%	0.10	0.07	0.0043	0.93	602	0.01	0.28
RSL - de minimis (IDOT)[§§]	%	0.12	0.09	0.000001	1.09	5,218	0.02	0.32
Antimony (Sb)								
Zhang & Frost (ISGS)[†]	mg/kg	0.9	0.9	0.2	2	90	0.6	1.3
Dreher & Follmer (ISGS)[§]	—							
Smith et al. (USGS)[‡]	mg/kg	0.83	0.72	0.27	9.1	88	0.46	1.04
IEPA (1994, Table 1)[¦]	mg/kg	3.7	3.6	0.18	8.6	142		
RSL - REC (IDOT)[¤]	mg/kg	1.8	1.1	0.0005	1,130	18,858	0.25	4.9
RSL - non-REC (IDOT)[††]	mg/kg	1.2	1.1	0.15	5.9	620	0.32	3.26
RSL - de minimis (IDOT) [§§]	mg/kg	1.3	1.1	0.00011	380	5,500	0.27	4.55
Arsenic (As)								
Zhang & Frost (ISGS)[†]	mg/kg	8.7	8.3	1.6	17	90	4.5	14
Dreher & Follmer (ISGS)[§]	—							
Smith et al. (USGS)[‡]	mg/kg	7.5	7.2	2	17.6	88	4.1	11.9
IEPA (1994, Table 1)[¦]	mg/kg	6.7	5.9	0.4	24	234		
RSL - REC (IDOT)[¤]	mg/kg	7.0	6.5	0.0055	390	18,717	2.0	13.0
RSL - non-REC (IDOT)[††]	mg/kg	6.2	6	0.68	32	620	1.9	11.0
RSL - de minimis (IDOT)[§§]	mg/kg	6.6	6.3	0.0007	170	5,500	2.3	11.6

	Unit	Mean	Median	Minimum	Maximum	n > DT*	5th percentile	95th percentile
Barium (Ba)								
Zhang & Frost (ISGS)[†]	mg/kg	566	582	245	805	90	400	715
Dreher & Follmer (ISGS)[§]	mg/kg	564	574	65	1,216	137	259	792
Smith et al. (USGS)[‡]	mg/kg	543	552	329	784	88	377	658
IEPA (1994, Table 1)[¦]	mg/kg	130	1,119	<5	1,720			
RSL - REC (IDOT)[¤]	mg/kg	80	62	0.0055	3,200	18,875	11.9	194
RSL - non-REC (IDOT)[††]	mg/kg	56	46	4.6	630	620	14	120
RSL - de minimis (IDOT)[§§]	mg/kg	60	52	0.0042	2,300	5,500	14	120
Beryllium (Be)								
Zhang & Frost (ISGS)[†]	mg/kg	1.4	1.3	<1	2.8	75	1	1.8
Dreher & Follmer (ISGS)[§]	—							
Smith et al. (USGS)[‡]	mg/kg	1.3	1.2	0.6	4.4	88	0.8	1.6
IEPA (1994, Table 1)[¦]	mg/kg	0.7	0.6	<0.02	9.9	213		
RSL - REC (IDOT)[¤]	mg/kg	0.59	0.58	0.000225	8.15	18,883	0.16	0.97
RSL - non-REC (IDOT)[††]	mg/kg	0.50	0.51	0.095	1.38	620	0.17	0.84
RSL - de minimis (IDOT)[§§]	mg/kg	0.57	0.58	0.000043	7.8	5,500	0.21	0.90
Cadmium (Cd)								
Zhang & Frost (ISGS)[†]	mg/kg	<4				0		
Dreher & Follmer (ISGS)[§]	—							
Smith et al. (USGS)[‡]	mg/kg	0.3	0.3	<0.1	2.8	84	0.1	0.8
IEPA (1994, Table 1)[¦]	mg/kg	1	0.5	<0.2	8.2			
RSL - REC (IDOT)[¤]	mg/kg	0.37	0.23	0.0003	110	18,887	0.061	0.93
RSL - non-REC (IDOT)[††]	mg/kg	0.29	0.21	0.015	2.24	620	0.064	0.7705
RSL - de minimis (IDOT)[§§]	mg/kg	0.36	0.26	0.000053	39	5,500	0.065	0.84
Chromium (Cr)								
Zhang & Frost (ISGS)[†]	mg/kg	55.9	58	19	91	90	40	65
Dreher & Follmer (ISGS)[§]	mg/kg	79.9	60	<5	1,311	128	13	174
Smith et al. (USGS)[‡]	mg/kg	39.1	39	10	73	88	24	54
IEPA (1994, Table 1)[¦]	mg/kg	17.1	14	<2.1	151	0	261	
RSL - REC (IDOT)[¤]	mg/kg	15.46	15	0.0041	870	18,875	4.6	25.93
RSL - non-REC (IDOT)[††]	mg/kg	14.89	14	2.6	480	620	4.7	24
RSL - de minimis (IDOT)[§§]	mg/kg	15.13	15	0.0011	190	5,500	5.4	24
Cobalt (Co)								
Zhang & Frost (ISGS)[†]	mg/kg	10.7	10.9	2.8	21	90	6.5	15
Dreher & Follmer (ISGS)[§]	—							
Smith et al. (USGS)[‡]	mg/kg	10.1	9.9	3.4	17.5	88	5.5	15.4
IEPA (1994, Table 1)[¦]	mg/kg	8.9	8.8	0.9	32	214		
RSL - REC (IDOT)[¤]	mg/kg	8.27	8	0.0054	130	16,904	2.3	15
RSL - non-REC (IDOT)[††]	mg/kg	7.84	7.45	1.4	32	610	2.545	14
RSL - de minimis (IDOT)[§§]	mg/kg	8.32	8.1	0.00064	96	5,231	2.5	15

	Unit	Mean	Median	Minimum	Maximum	n > DT*	5th percentile	95th percentile
Copper (Cu)								
Zhang & Frost (ISGS)[†]	mg/kg	27.9	25	8	69	90	12	53
Dreher & Follmer (ISGS)[§]	mg/kg	24.5	23	<5	53	135	17	38
Smith et al. (USGS)[‡]	mg/kg	20.1	16.5	6.9	166	88	10.4	44.9
IEPA (1994, Table 1)[¦]	mg/kg	19.7	14	1	156	254		
RSL - REC (IDOT)[¤]	mg/kg	22.83	18.7	0.003	5,900	18,892	5	38
RSL - non-REC (IDOT)[††]	mg/kg	20.59	18	2	360	620	5.9	40
RSL - de minimis (IDOT)[§§]	mg/kg	19.83	19	0.002	970	5,500	6.7	33
Lead (Pb)								
Zhang & Frost (ISGS)[†]	mg/kg	26.9	20	<10	250	87	10	50
Dreher & Follmer (ISGS)[§]	mg/kg	28.8	22	<5	308	135	16	50
Smith et al. (USGS)[‡]	mg/kg	26.1	23.8	15.1	75.9	88	17.1	45.1
IEPA (1994, Table 1)[¦]	mg/kg	49.2	25	4.7	647	267		
RSL - REC (IDOT)[¤]	mg/kg	47.99	15	0.0055	68,000	18,892	4.195	130
RSL - non-REC (IDOT)[††]	mg/kg	30.42	15	1.9	670	620	4.2	110
RSL - de minimis (IDOT)[§§]	mg/kg	48.26	15	0.0012	38,000	5,500	5.17	140
Mercury (Hg)								
Zhang & Frost (ISGS)[†]	—							
Dreher & Follmer (ISGS)[§]	mg/kg	0.038	0.03	<0.002	0.471	134	0.016	0.08
Smith et al. (USGS)[‡]	mg/kg	0.041	0.03	0.02	0.13	88	0.02	0.09
IEPA (1994, Table 1)[¦]	mg/kg	0.11	0.06	<0.001	1.67	200		
RSL - REC (IDOT)[¤]	mg/kg	0.16	0.028	0.0000012	700	18,873	0.01	0.12
RSL - non-REC (IDOT)[††]	mg/kg	0.04	0.026	0.005	1	620	0.0097	0.08
RSL - de minimis (IDOT)[§§]	mg/kg	0.03	0.026	0.0000023	7.3	5,500	0.01	0.06
Nickel (Ni)								
Zhang & Frost (ISGS)[†]	mg/kg	22.4	18	<20	53	22	13	44
Dreher & Follmer (ISGS)[§]	mg/kg	20.1	21	<5	49	128	7	37
Smith et al. (USGS)[‡]	mg/kg	16.6	16.5	6.6	40.5	88	9.5	23.3
IEPA (1994, Table 1)[¦]	mg/kg	16.8	14.1	<3	135			
RSL - REC (IDOT)[¤]	mg/kg	19.4	18.8	0.0033	880	18,877	5.06	35.1
RSL - non-REC (IDOT)[††]	mg/kg	18.5	18	3	56	620	5.8	33
RSL - de minimis (IDOT)[§§]	mg/kg	19.7	19	0.0015	100	5,500	6.1	34
Selenium (Se)								
Zhang & Frost (ISGS)[†]	mg/kg	<1	2.6	15				
Dreher & Follmer (ISGS)[§]	—							
Smith et al. (USGS)[‡]	mg/kg	0.5	0.5	0.2	2.8	85	0.3	0.7
IEPA (1994, Table 1)[¦]	mg/kg	0.5	0.4	<0.1	2.6	200		
RSL - REC (IDOT)[¤]	mg/kg	0.7	0.6	0.0	20.0	18,859	0.3	1.3
RSL - non-REC (IDOT)[††]	mg/kg	0.6	0.6	0.2	5.8	620	0.3	1.1
RSL - de minimis (IDOT)[§§]	mg/kg	0.7	0.6	0.0	23.2	5,500	0.3	1.2

	Unit	Mean	Median	Minimum	Maximum	n > DT*	5th percentile	95th percentile
Thallium (Tl)								
Zhang & Frost (ISGS)†	mg/kg	1.4	1	<1	3	74	1	2
Dreher & Follmer (ISGS)§	—							
Smith et al. (USGS)‡	mg/kg	0.5	0.5	0.3	1.4	88	0.3	0.7
IEPA (1994, Table 1)¦	mg/kg	0.6	0.4	0	2.8	191		
RSL - REC (IDOT)¤	mg/kg	1.0	0.6	0.005	38	18,856	0.2	2.6
RSL - non-REC (IDOT)††	mg/kg	0.7	0.6	0.13	3.5	620	0.3	2.4
RSL - de minimis (IDOT)§§	mg/kg	0.7	0.6	0.000027	23.3	5,500	0.2	2.5
Vanadium (V)								
Zhang & Frost (ISGS)†	mg/kg	84.6	81.5	22	260	90	43	137
Dreher & Follmer (ISGS)§	mg/kg	76	74	<35	117	135	54	104
Smith et al. (USGS)‡	mg/kg	56.9	58	21	89	88	35	76
IEPA (1994, Table 1)¦	mg/kg	25	25	<2.5	80	214		
RSL - REC (IDOT)¤	mg/kg	21.4	20	0.0054	190	16,904	7.6	39.6
RSL - non-REC (IDOT)††	mg/kg	19.0	19	3.9	150	610	8.1	30.55
RSL - de minimis (IDOT)§§	mg/kg	20.0	19.8	0.0015	370	5,231	8.8	31.1
Zinc (Zn)								
Zhang & Frost (ISGS)†	mg/kg	72.6	64	19	258	90	33	143
Dreher & Follmer (ISGS)§	mg/kg	73	67	<5	348	135	36	138
Smith et al. (USGS)‡	mg/kg	79.5	73	29	288	88	41	141
IEPA (1994, Table 1)¦	mg/kg	102.9	67.4	<5	798	246		
RSL - REC (IDOT)¤	mg/kg	79.8	52	0.0024	160,000	18,840	16	150
RSL - non-REC (IDOT)††	mg/kg	56.1	47	4.3	460	620	18	110
RSL - de minimis (IDOT)§§	mg/kg	58.8	49	0.0036	8,200	5,500	20	100

[1] An asterisk (*) IEPA and IDOT. n = number of samples.

[2] Vertical sampling interval: †Zhang & Frost (ISGS): depth interval 0.1–0.2 m; §Dreher & Follmer (ISGS): top interval A horizon; ‡Smith (USGS): depth interval 0–0.2 m; ¦IEPA (1994, Table 1): various depths; ¤RSL - REC (IDOT): various depths from 0 to 3.05 m; ††RSL - non-REC (IDOT): various depths from 0 to 3.05 m; §§RSL - de minimis (IDOT): various depths from 0 to 3.05 m.

Table 2. Comparison of Soil Analyte Natural Background Concentrations in A horizon (~0 to 20 cm) and RSL 95% Confidence Level Concentrations (All Depths)

	Source							
	—	—	TACO section 742, Table G	TACO section 742, Table G	Cahill (2017)	IDOT RSL	IDOT RSL	IDOT RSL
Constituent[1]	Study used (background)	Unit in this table	MSA counties (background)	Non-MSA counties (background)	95% confidence level (background)	REC, 95% confidence level	Non-REC, 95% confidence level	de minimis, 95% confidence level
Aluminum	Dreher	mg/kg	9,500	9,200	61,500	16,000	14,000	15,000
Antimony*	USGS	mg/kg	4	3.3	1.04	4.9	3.26	4.55
Arsenic*	USGS	mg/kg	13	11.3	11.9	13	11.04	11.605
Barium	Dreher	mg/kg	110	122	792	194	120	120
Beryllium	USGS	mg/kg	0.59	0.56	1.6	0.97	0.84	0.90
Cadmium*	USGS	mg/kg	0.6	0.5	0.8	0.93	0.7705	0.84
Calcium	Dreher	mg/kg	9,300	5,525	21,250	130,000	127,850	130,000
Chromium	USGS	mg/kg	16.2	13	54	25.93	24	24
Cobalt	USGS	mg/kg	8.9	8.9	15.4	15	14	15
Copper	USGS	mg/kg	19.6	12	44.9	38	40	33
Iron*	Dreher	mg/kg	15,900	1,500	35,700	28,100	25,055	26,000
Lead*	USGS	mg/kg	36	20.9	45.1	130	110	140
Magnesium	Dreher	mg/kg	4,820	2,700	10,450	62,000	69,000	69,000
Manganese*	Dreher	mg/kg	636	630	1924	970	860	870
Mercury	Dreher	mg/kg	0.06	0.05	0.08	0.12	0.08	0.06
Nickel	USGS	mg/kg	18	13	23.3	35.1	33	34
Potassium	Dreher	mg/kg	1,268	1,100	22,075	3,194	2,900	3,200
Selenium	USGS	mg/kg	0.48	0.37	0.7	1.3	1.1	1.2
Sodium	Dreher	mg/kg	130	130	8,300	2,100	2,095	2,400
Thallium	USGS	mg/kg	0.32	0.42	0.7	2.6	2.41	2.45
Vanadium	USGS	mg/kg	25.2	25	104	39.6	30.55	31.1
Zinc	USGS	mg/kg	95	60.2	141	150	110	100

[1]An asterisk (*) indicates the analyte is discussed in greater detail in the section titled "Review of Priority Soil Constituents." TACO is tiered approach to corrective action objectives and MSA is metropolitan statistical area.

REVIEW OF PRIORITY SOIL CONSTITUENTS

This review of priority constituents is presented for analytes on a statewide basis. These constituents were chosen by IDOT for additional discussion because of their frequent detection during PSI work. The RSL analysis by spatial subset (IDOT region, IDOT district, county) is presented in the appendices (Anderson & Yacucci, 2021a). The RSL data presented were obtained from all sample depths (0 to 3.05 m [0 to 10 ft]). A general observation that applies to all priority analytes is that the largest number of samples and widest spatial coverage are for sites classified as REC (compared with non-REC and de minimis). This observation holds true for all analytes; therefore, the RSL database is predominantly composed of REC soils because of differences in testing procedures, which vary by IDOT district. Additionally, because of the smaller number of observations for non-REC and de minimis sites, the confidence interval on the median (notch) is larger than that for REC sites and often extends beyond the first and third quartiles. A preliminary environmental site assessment (PESA) is completed for projects in which land acquisition is required for additional ROWs or easements, the land is adjacent to a railroad ROW, or the land requires excavation or the location of a subsurface utility. The PESA evaluates the history of land use and determines whether a site is a REC, is a non-REC, or has de minimis conditions. Because District 1 is in a more urbanized setting, samples were collected for both REC and non-REC sites. For Districts 2 through 9, only REC sites were sampled. IDOT does not assume a site is affected solely because it is identified as a REC. A site with a REC indicates that releases have occurred or potential releases of hazardous substances may have occurred on, at, in, or adjoining the site. Sites classified as REC are the subject of a PSI to further evaluate site conditions for proper soil management during construction or to identify pollution point sources.

Antimony

As shown in Table 1, the mean concentration of antimony ranges from 1.2 to 1.8 mg/kg across IDOT soil contamination categories. A range of 0.9 to 3.7 mg/kg was observed for the mean among the reviewed studies of natural soils. The median for antimony in the RSL database is 1.1 mg/kg. A range of 0.72 to 3.6 mg/kg was observed for the median among the reviewed studies of natural soils. The 95% confidence level for antimony in the RSL database ranges from 3.26 to 4.9 mg/kg across IDOT soil contamination categories. A range of 1.04 to 1.3 mg/kg was observed for the 95% confidence level among the reviewed studies of natural soils; a significant difference was found in the magnitude of the mean and median. The mean and median magnitudes in the studies by both Zhang and Frost and Smith et al. are significantly smaller than those for the IEPA (1994, Table 1). The RSL mean and median values are larger than those in both the Zhang and Frost and Smith et al. studies and smaller than those for the IEPA (1994, Table 1). The 95% confidence level was not calculated for the IEPA study, although by definition, the 95% confidence level cannot be less than the mean. The 95% confidence level of 3.26 to 4.9 mg/kg for the RSL database is similar to but larger than the mean and median of 3.7 and 3.6 mg/kg, respectively, from the IEPA (1994, Table 1).

As shown in Table 2, the current tiered approach to corrective action objectives (TACO) thresholds for metropolitan statistical area (MSA) and non-MSA counties (3.3 to 4.0 mg/kg) are similar to the range of magnitudes observed in the RSL database. The threshold proposed by Cahill (2017) is lower than the current TACO-recommended values (1.04 mg/kg) and is smaller than the median for many IDOT districts as grouped by REC type.

Histograms of statewide antimony concentrations in the RSL show a bimodal distribution with a primary peak between 1.0 and 1.2 mg/kg and a secondary smaller peak around 5.0 mg/kg (see Figure 5 to Figure 7). Boxplots by IDOT district show significant differences between IDOT districts, particularly for REC sites (see Figure 8 to Figure 10). The bin size (range of values represented as a single probability density, i.e., width of bars in histogram) is 0.2 mg/kg.

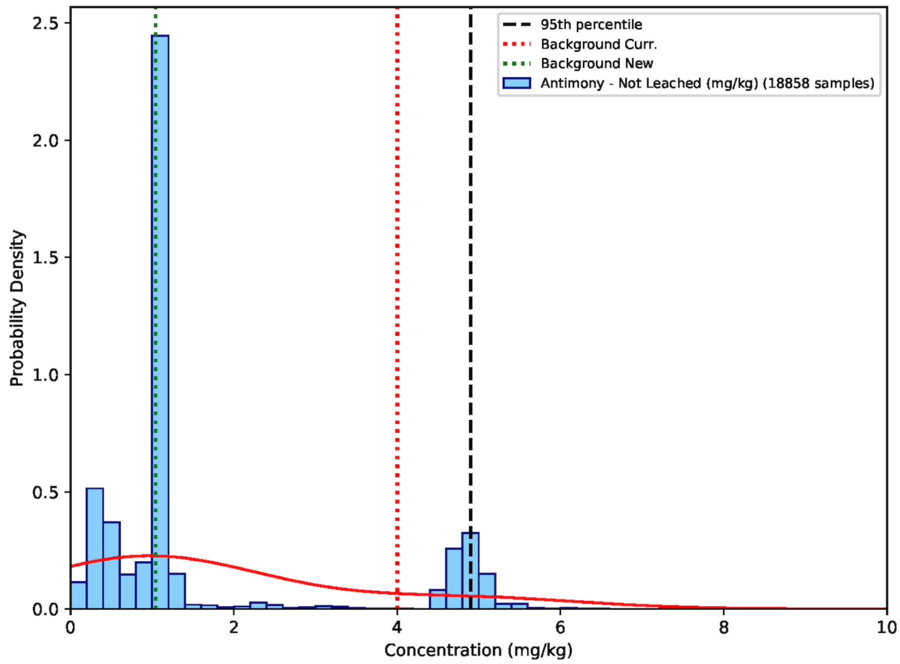

Figure 5. Histogram of RSL antimony concentrations, REC (mg/kg).

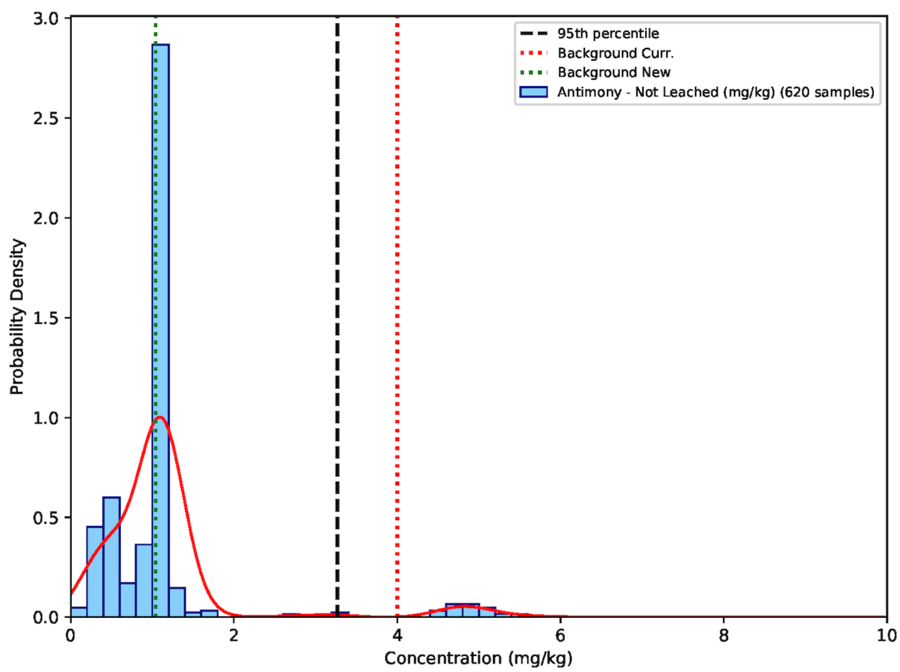

Figure 6. Histogram of RSL antimony concentrations, non-REC (mg/kg).

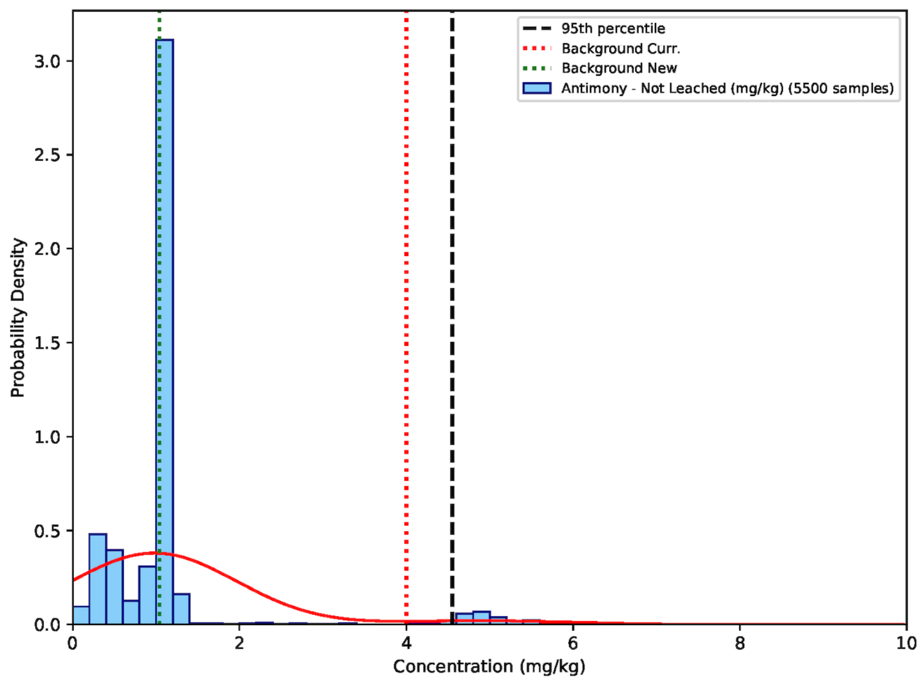

Figure 7. Histogram of RSL antimony concentrations, de minimis (mg/kg).

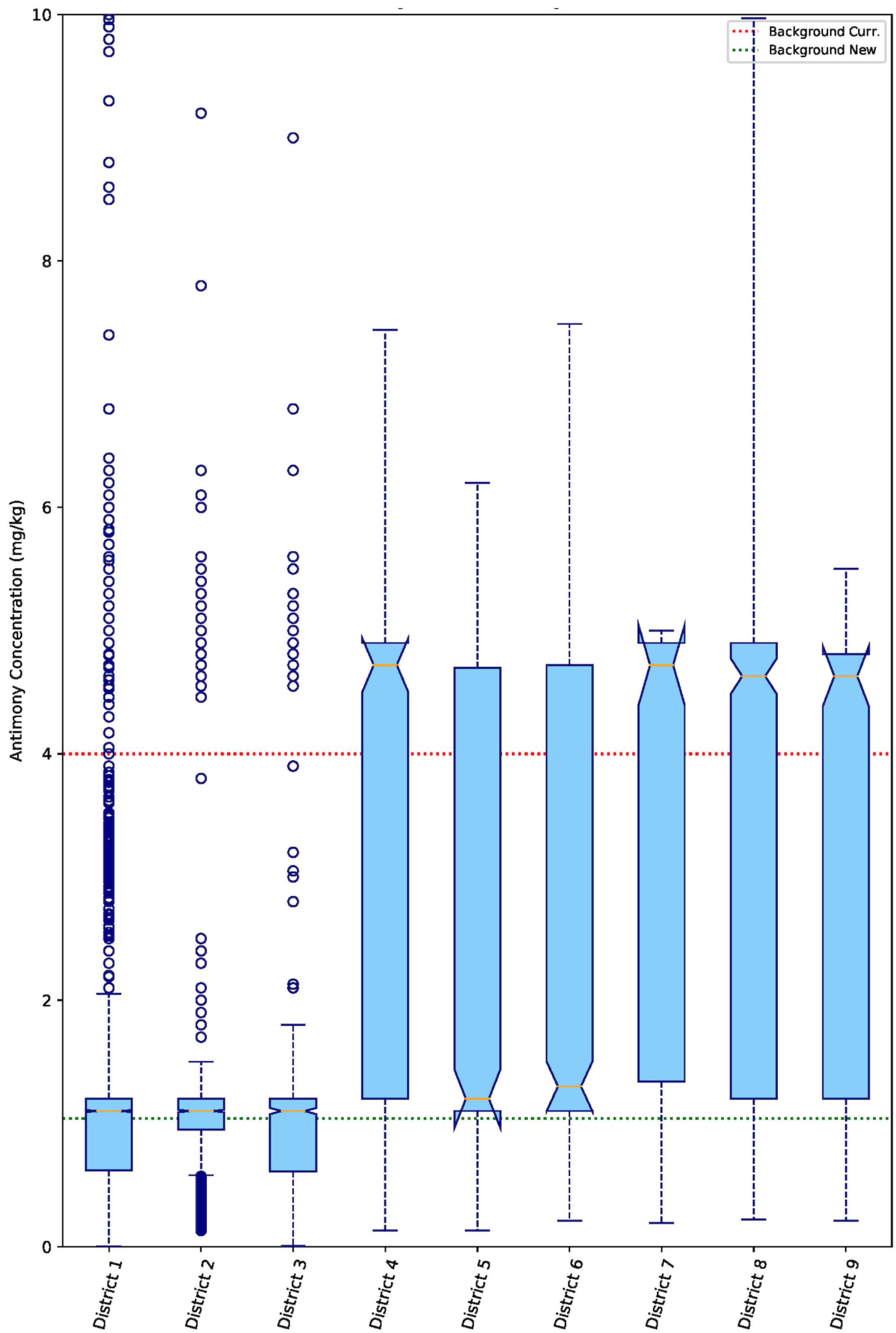

Figure 8. Boxplot of RSL antimony concentrations, REC (mg/kg).

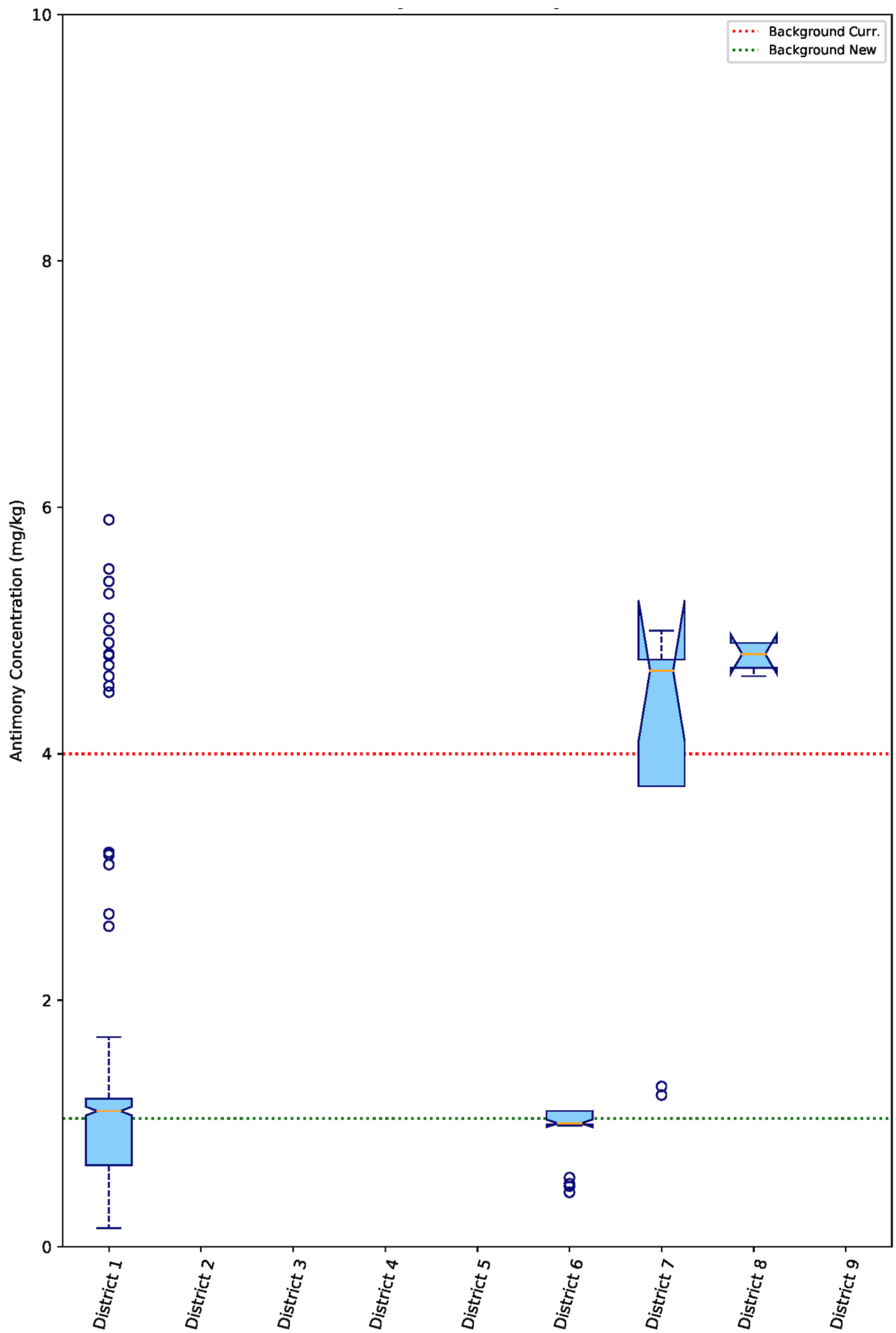

Figure 9. Boxplot of REC antimony concentrations, non-REC (mg/kg).

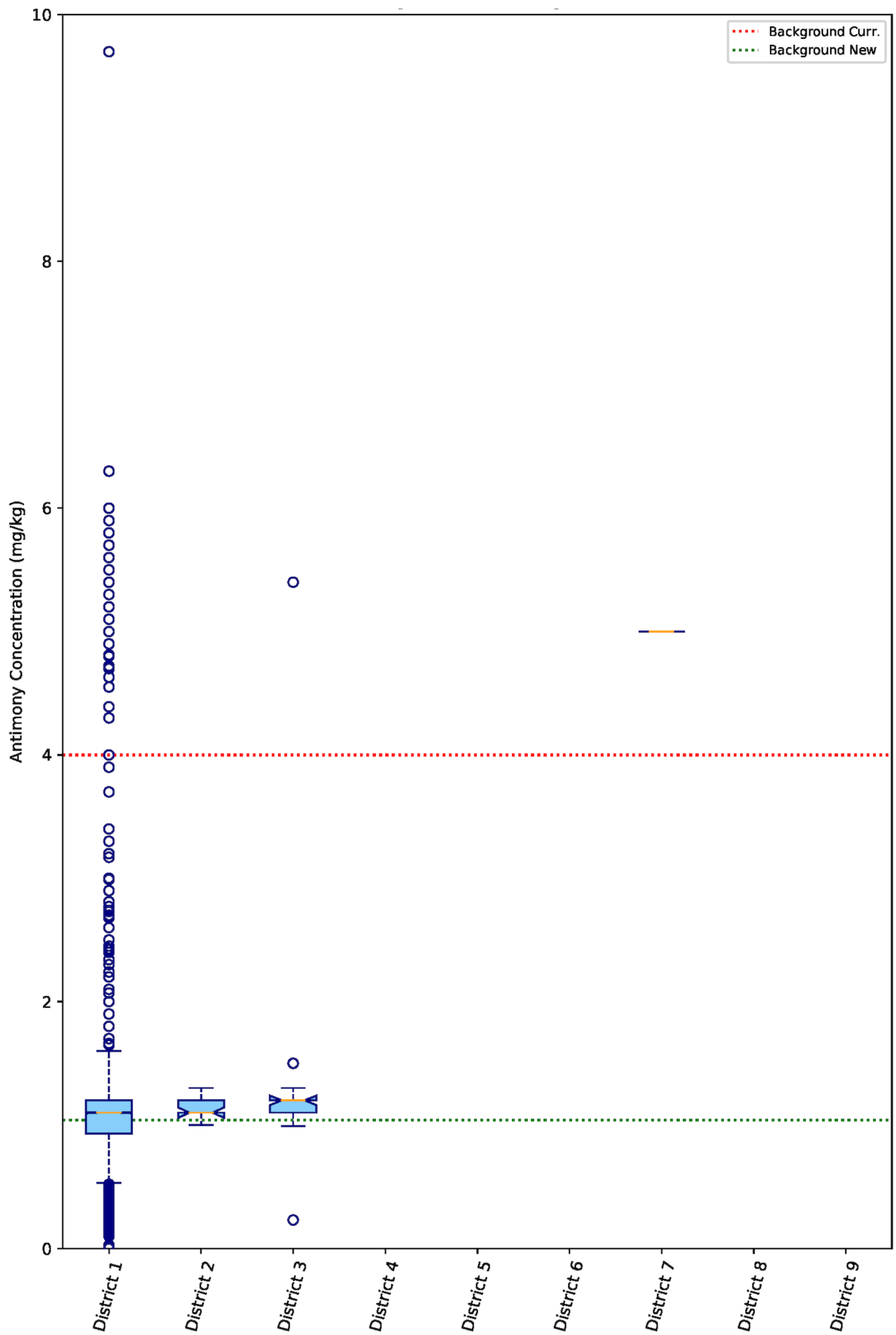

Figure 10. Boxplot of RSL antimony concentrations, de minimis (mg/kg).

Arsenic

As shown in Table 1, the mean concentration of arsenic ranges from 6.2 to 7.0 mg/kg across IDOT soil contamination categories. A range of 6.7 to 8.7 mg/kg was observed for the mean among the reviewed studies of natural soils. The median for arsenic in the RSL database ranges from 6.0 to 6.5 mg/kg. A range of 5.9 to 8.3 mg/kg was observed for the median among the reviewed studies of natural soils. The 95% confidence level for arsenic in the RSL database ranges from 11.0 to 13.0 mg/kg across IDOT soil contamination categories. A range of 11.9 to 14.0 mg/kg was observed for the 95% confidence level among the reviewed studies of natural soils.

As shown in Table 2, the current TACO thresholds for MSA and non-MSA counties (11.3 to 13.0 mg/kg) are similar to the range of magnitudes observed in the RSL database and natural soils. The threshold proposed by Cahill (2017) is similar to the current TACO-recommended values (11.9 mg/kg).

Histograms of statewide concentrations in the RSL show a dominant peak between 4.8 and 7.2 mg/kg (see Figure 11 to Figure 13). Boxplots by IDOT district show moderate differences between IDOT districts (see Figure 14 to Figure 16). The histogram bin size is 0.8 mg/kg.

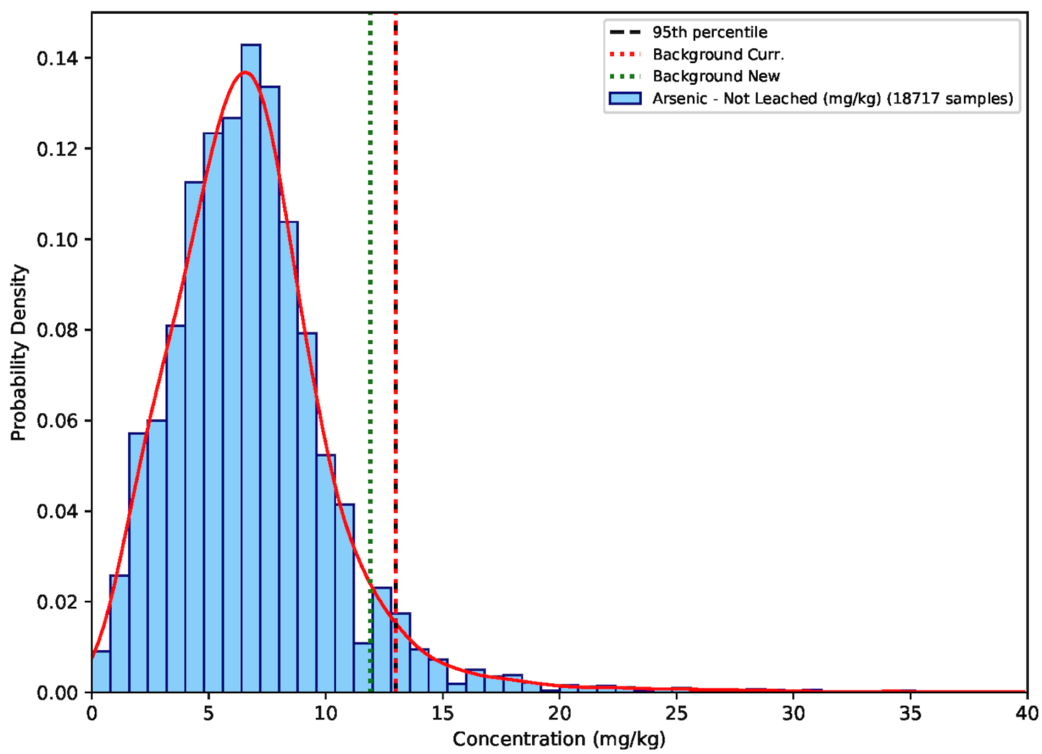

Figure 11. Histogram of RSL arsenic concentrations, REC (mg/kg).

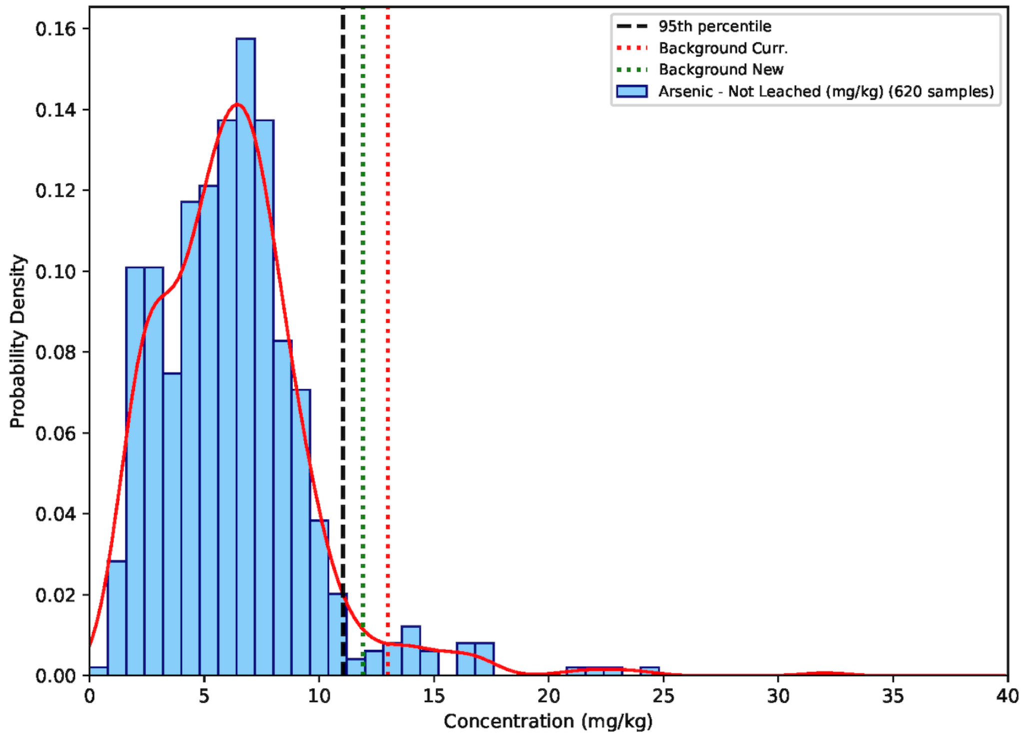

Figure 12. Histogram of RSL arsenic concentrations, non-REC (mg/kg).

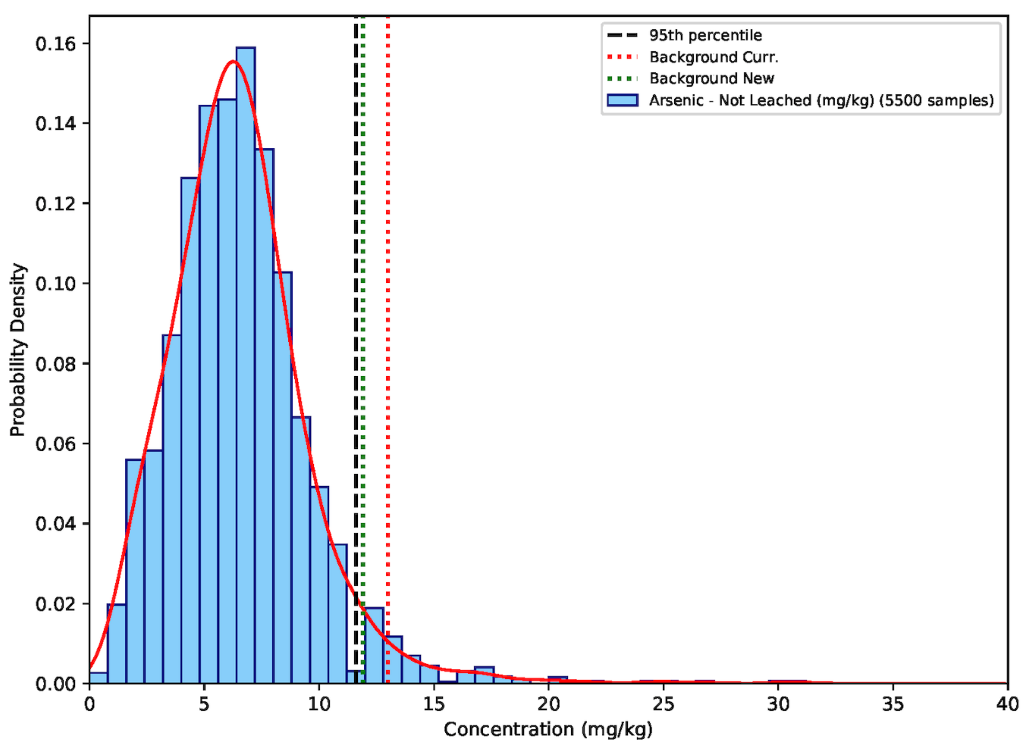

Figure 13. Histogram of RSL arsenic concentrations, de minimis (mg/kg).

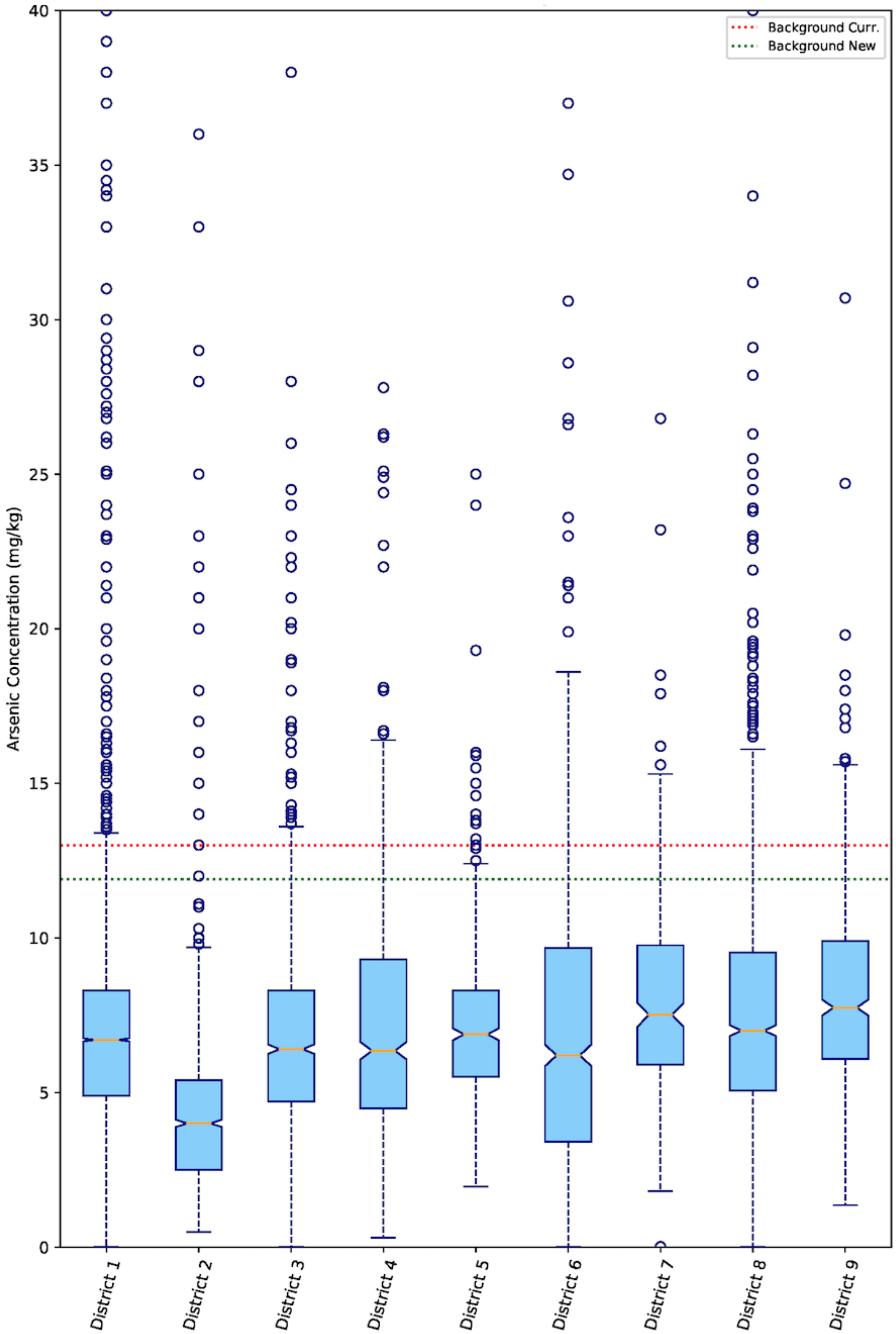

Figure 14. Boxplot of RSL arsenic concentrations, REC (mg/kg).

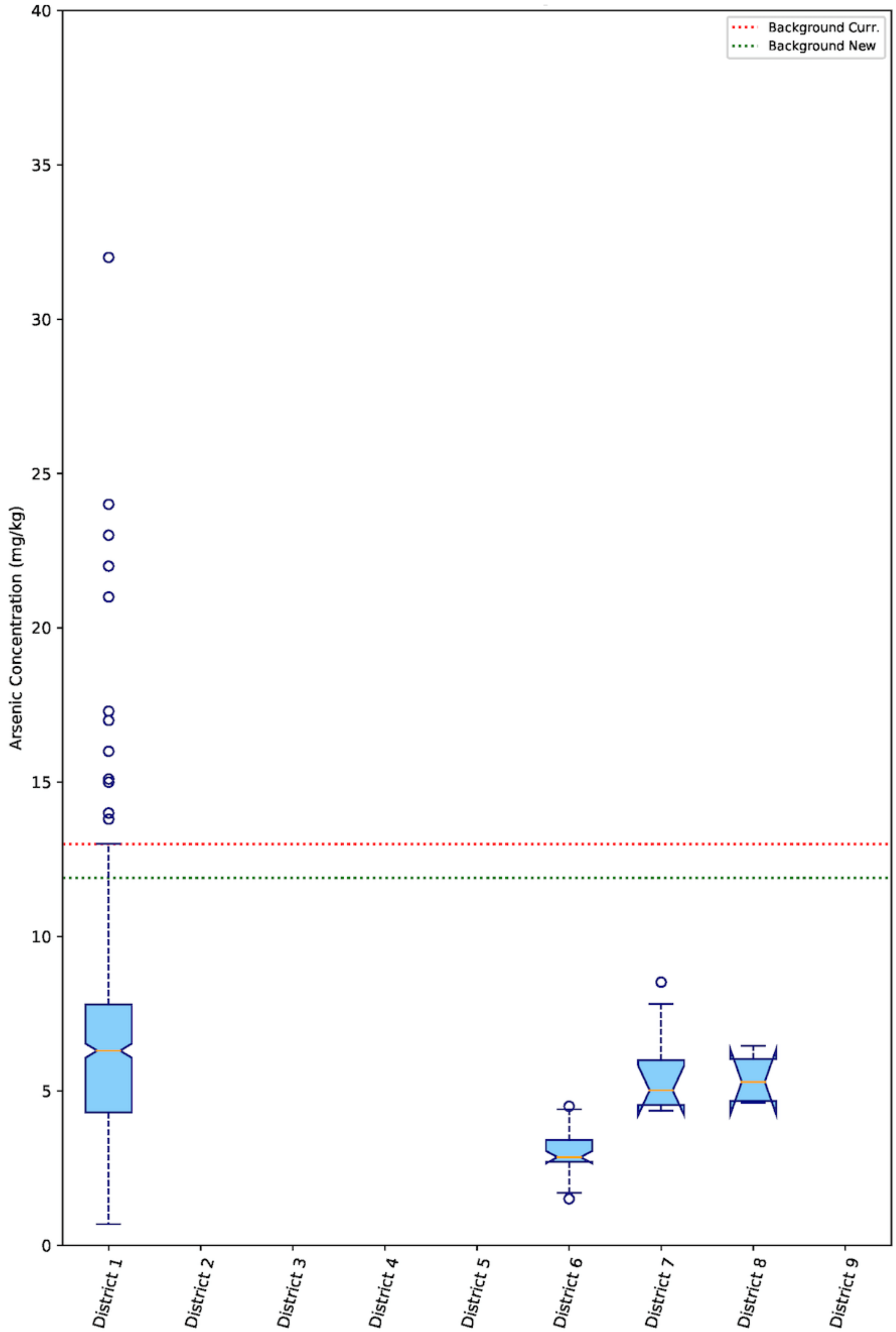

Figure 15. Boxplot of RSL arsenic concentrations, non-REC (mg/kg).

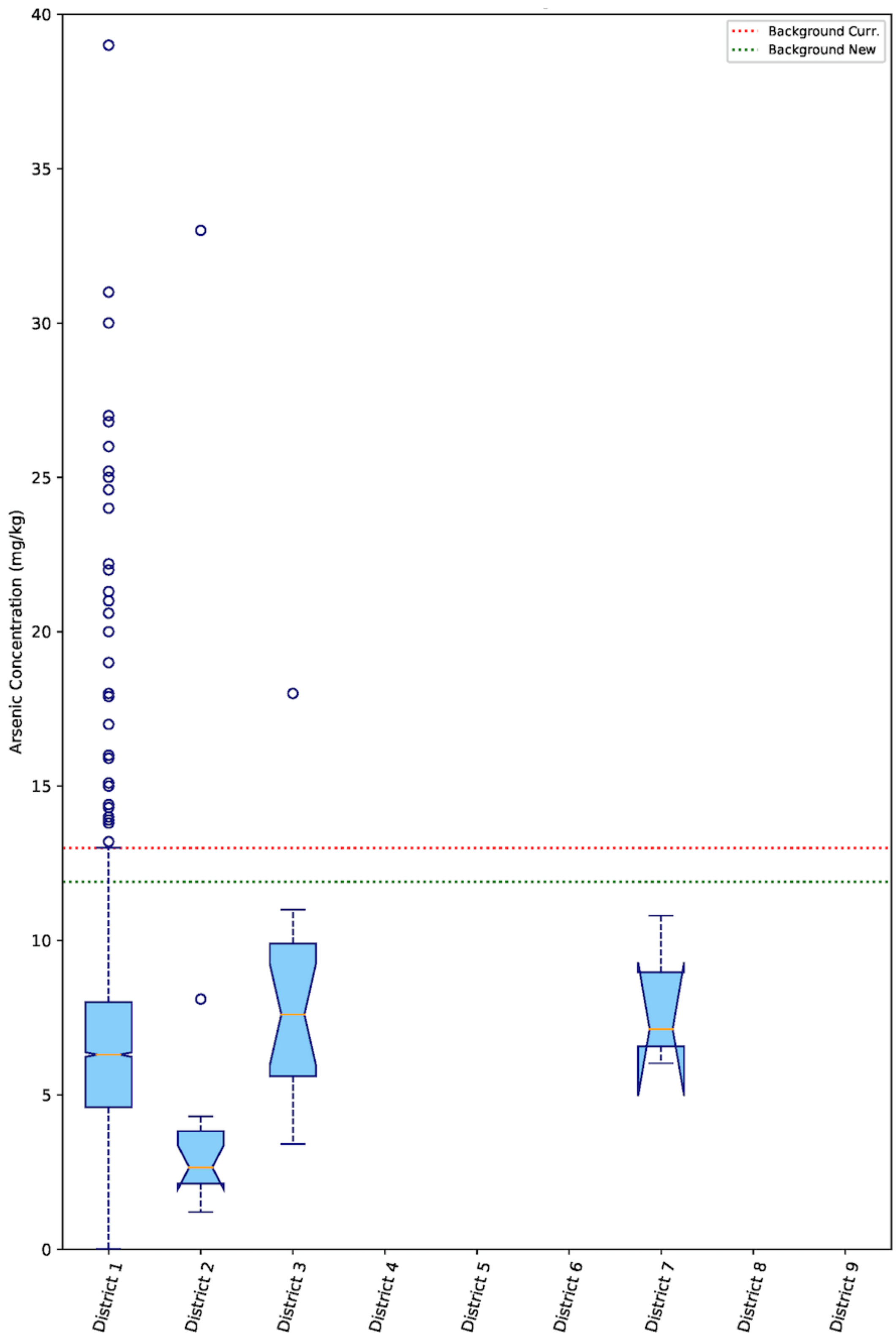

Figure 16. Boxplot of RSL arsenic concentrations, de minimis (mg/kg).

Cadmium

As shown in Table 1, the mean concentration of cadmium ranges from 0.29 to 0.37 mg/kg across IDOT soil contamination categories. A range of 0.3 to <4 mg/kg was observed for the mean among the reviewed studies of natural soils. The median for cadmium in the RSL database ranges from 0.21 to 0.26 mg/kg. A range of 0.3 to 0.5 mg/kg was observed for the median among the reviewed studies of natural soils. The 95% confidence level for cadmium in the RSL database ranges from 0.77 to 0.93 mg/kg across IDOT soil contamination categories. A magnitude of 0.8 mg/kg was observed for the 95% confidence level among the reviewed studies of natural soils.

As shown in Table 2, the current TACO thresholds for MSA and non-MSA counties (0.5 to 0.6 mg/kg) are smaller than the range of magnitudes observed in the RSL database. The threshold proposed by Cahill (2017) is slightly larger than the current TACO-recommended values (0.8 mg/kg) and is in better agreement with magnitudes observed in the RSL.

Histograms of statewide concentrations in the RSL show a dominant peak between 0.2 and 0.3 mg/kg (see Figure 17 to Figure 19). Boxplots by IDOT district show moderate to small differences between IDOT districts (see Figure 20 to Figure 22). The histogram bin size is 0.1 mg/kg.

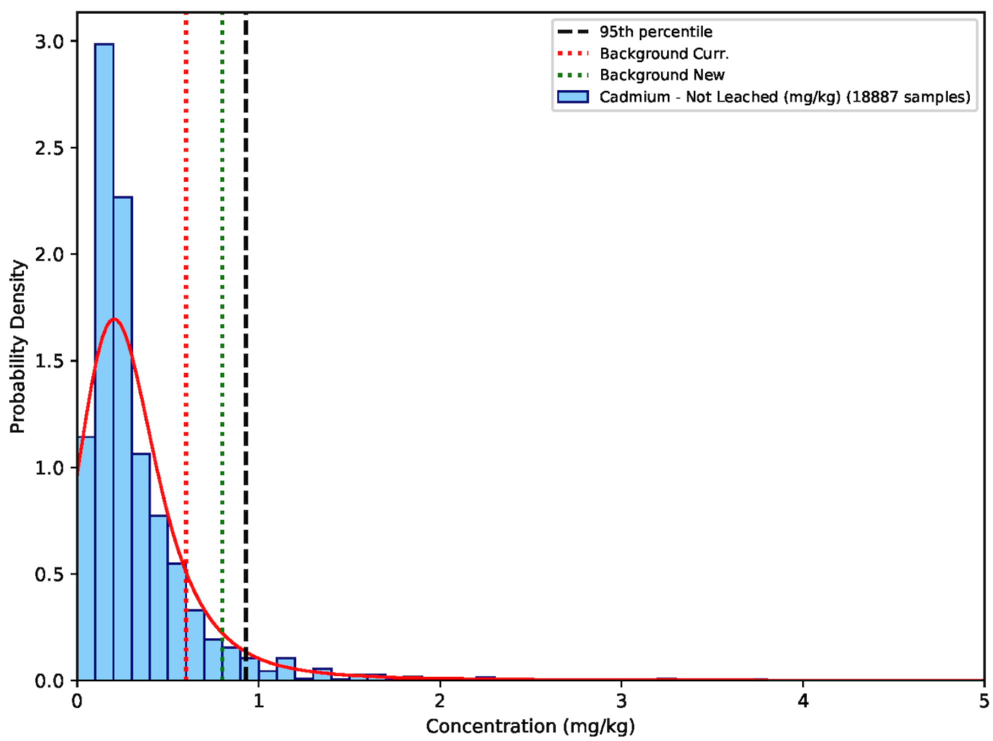

Figure 17. Histogram of RSL cadmium concentrations, REC (mg/kg).

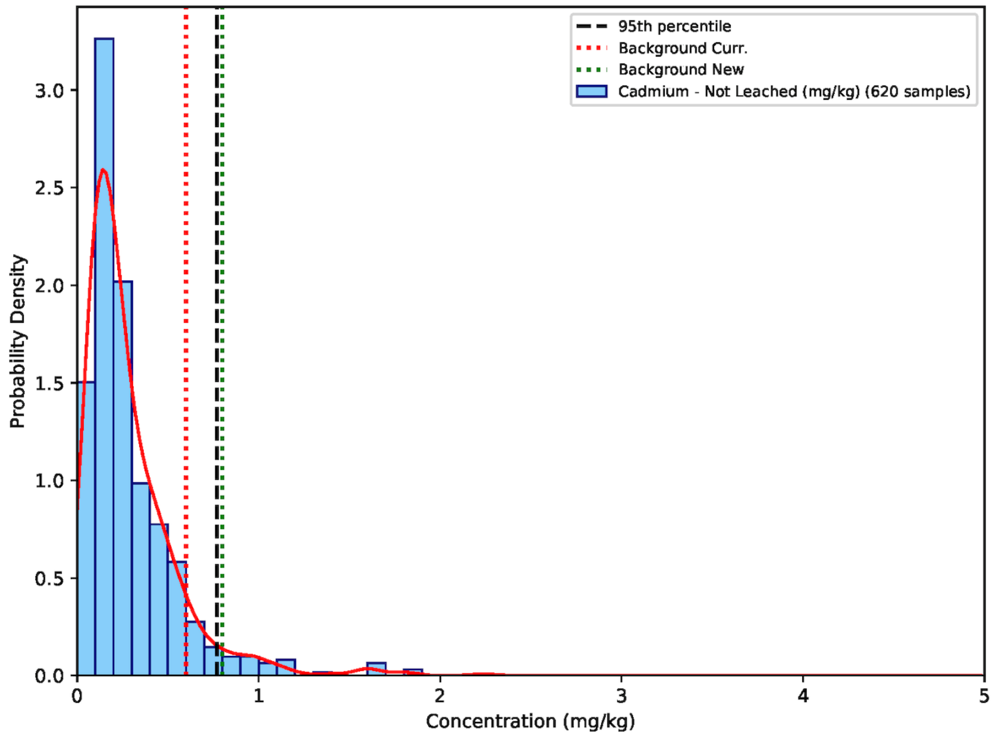

Figure 18. Histogram of RSL cadmium concentrations, non-REC (mg/kg).

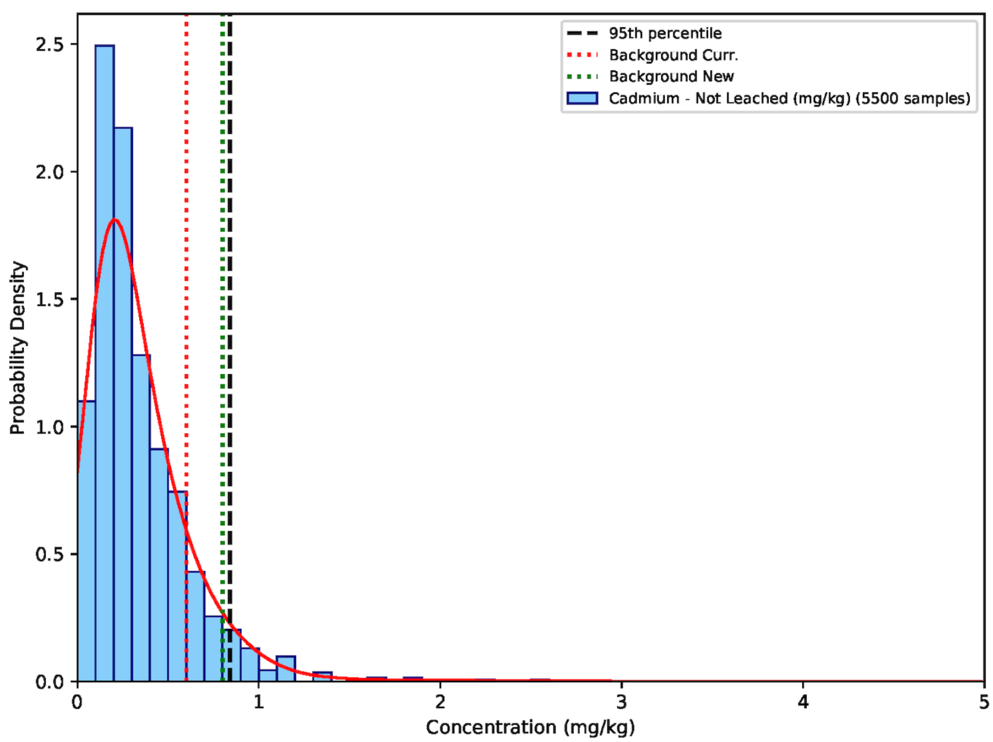

Figure 19. Histogram of RSL cadmium concentrations, de minimis (mg/kg).

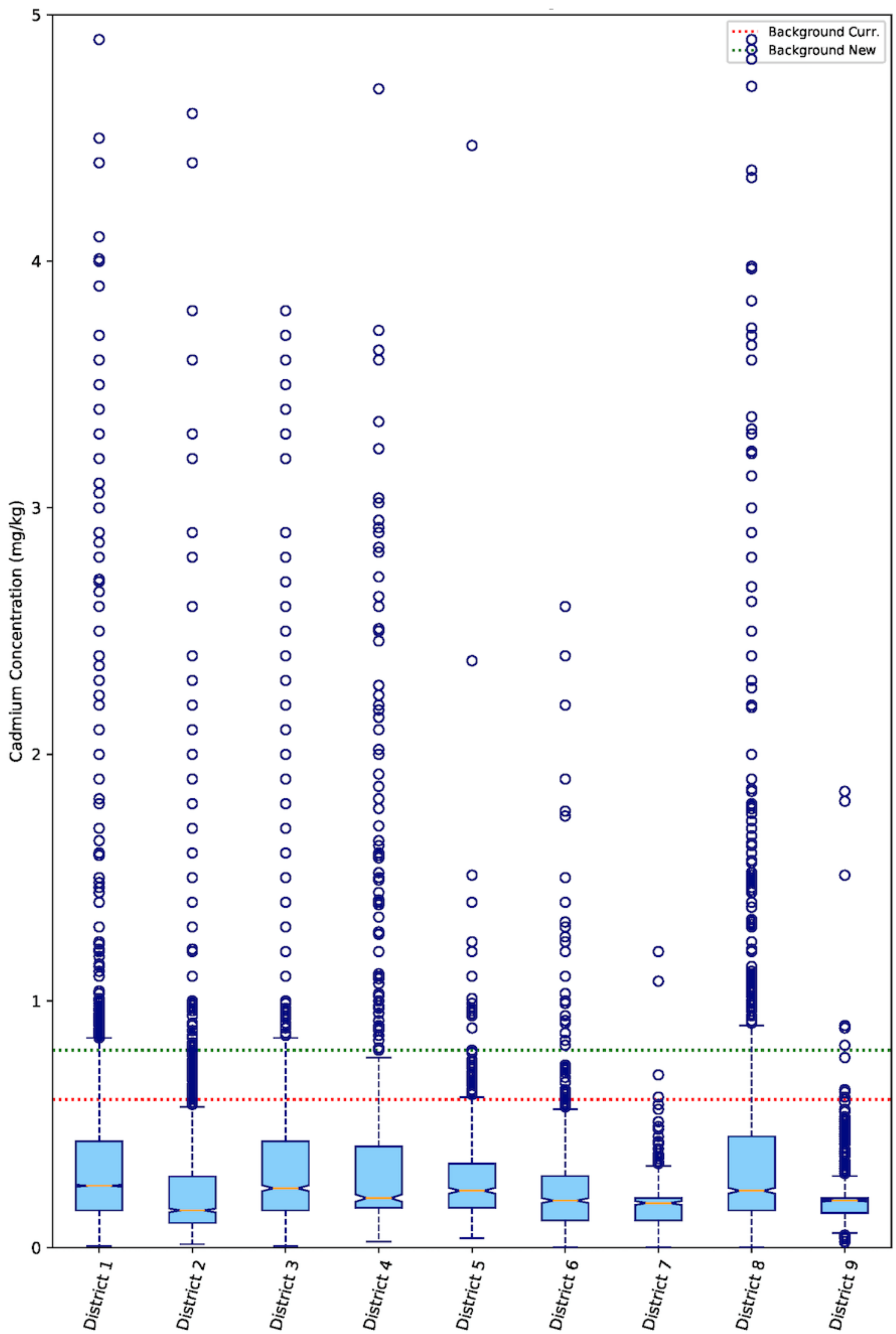

Figure 20. Boxplot of RSL cadmium concentrations, REC (mg/kg).

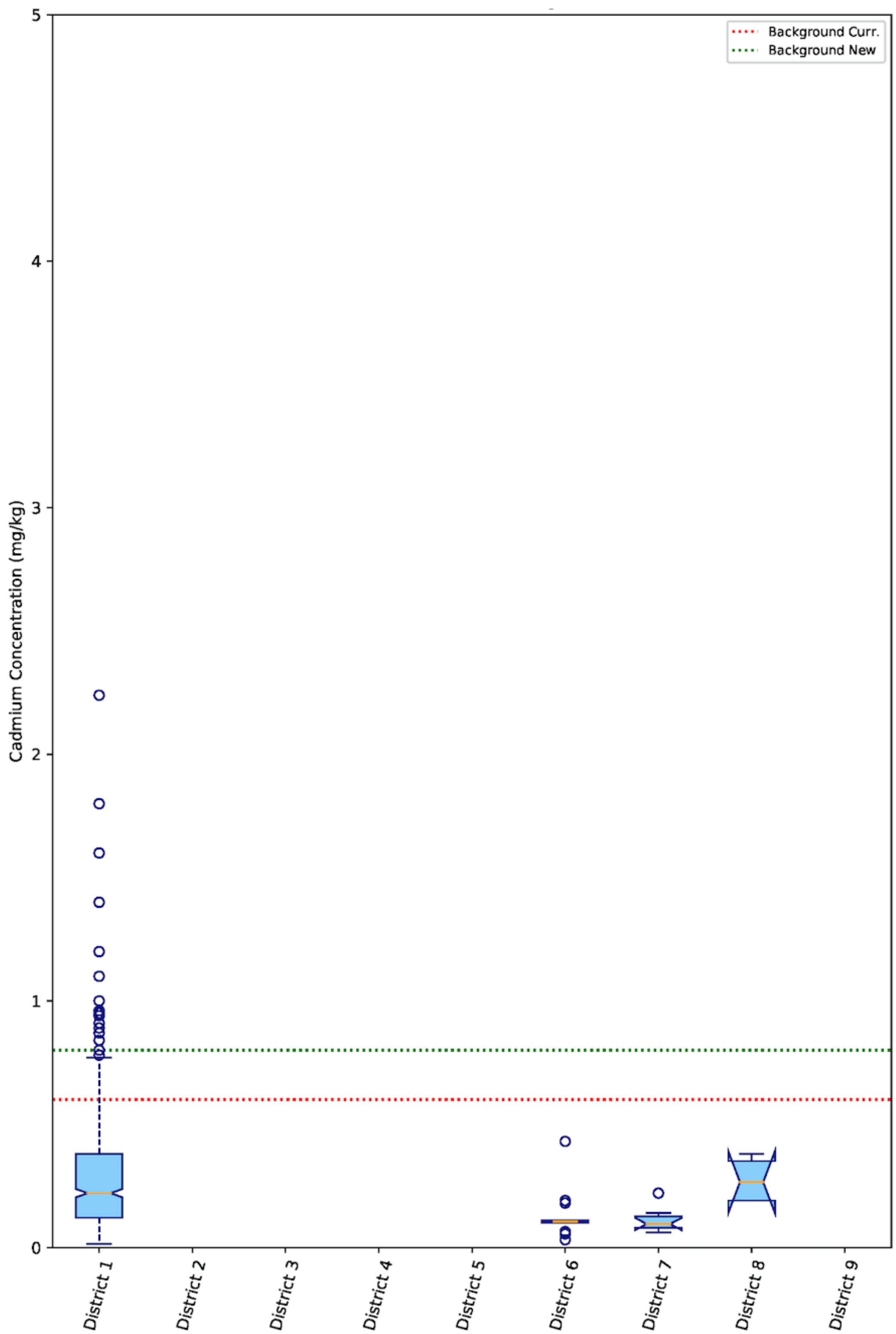

Figure 21. Boxplot of RSL cadmium concentrations, non-REC (mg/kg).

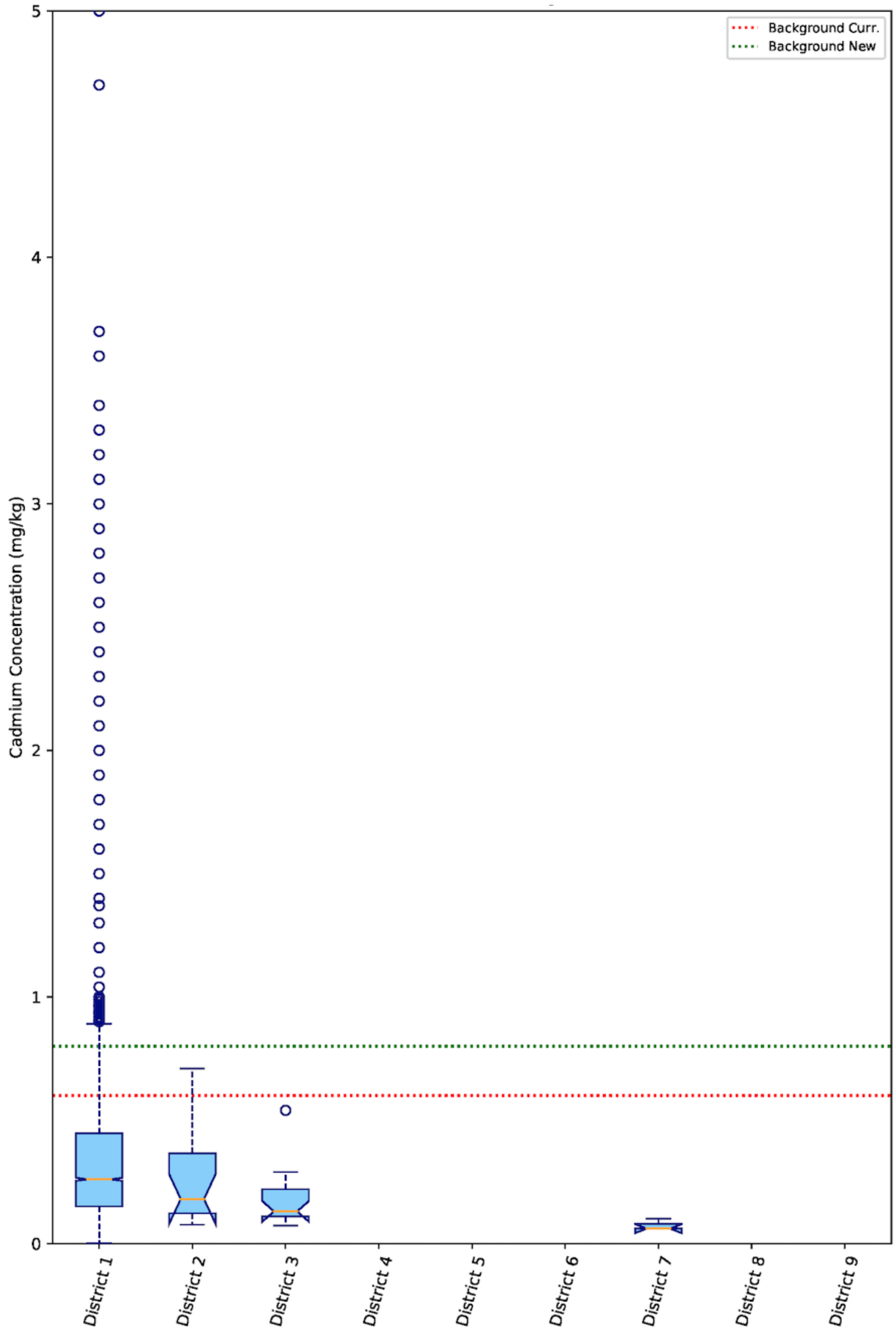

Figure 22. Boxplot of RSL cadmium concentrations, de minimis (mg/kg).

Iron

As shown in Table 1, the mean concentration of iron ranges from 15,064 to 16,934 mg/kg (4.82 to 5.41 wt% iron oxide) across IDOT soil contamination categories. The iron oxide examined was Fe_2O_3. A range of 7,224 to 10,570 mg/kg (2.31 to 3.38%) was observed for the mean among the reviewed studies of natural soils. The median for iron in the RSL database ranges from 15,050 to 17,000 mg/kg (4.81 to 5.44%). A range of 6,786 to 10,289 mg/kg (2.17 to 3.29%) was observed for the median among the reviewed studies of natural soils. The 95% confidence level for iron in the RSL database ranges from 25,055 to 28,100 mg/kg (8.01 to 8.99%) across IDOT soil contamination categories. A range of 12,509 to 15,981 mg/kg (4.00 to 5.11%) was observed for the 95% confidence level among the reviewed studies of natural soils.

As shown in Table 2, the current TACO thresholds for MSA and non-MSA counties (15,000 to 15,900 mg/kg) are similar to the mean and median of the RSL database and natural soils. The threshold proposed by Cahill (2017) is significantly larger than the current TACO-recommended values (35,700 mg/kg) and is above 95% confidence level values for the RSL database.

Histograms of statewide concentrations in the RSL show a wide, dominant peak with a maximum between 17,600 and 19,200 mg/kg (see Figure 23 to Figure 25). Boxplots by IDOT district show moderate to significant differences between IDOT districts (see Figure 26 to Figure 28). The histogram bin size is 800 mg/kg.

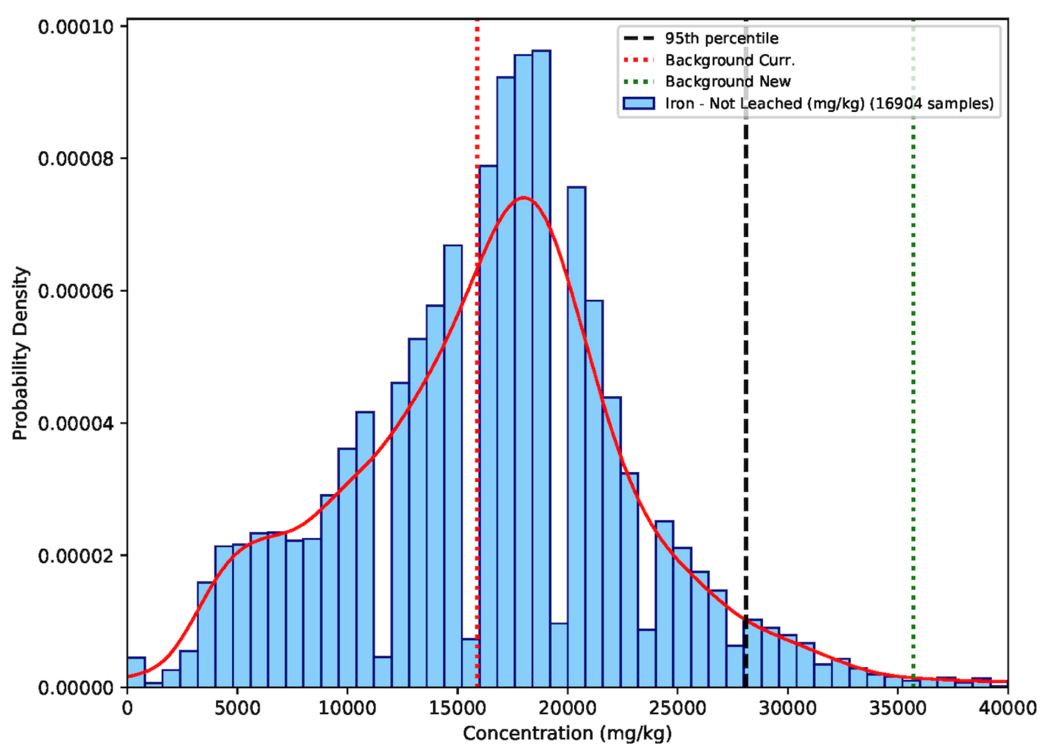

Figure 23. Histogram of RSL iron concentrations, REC (mg/kg).

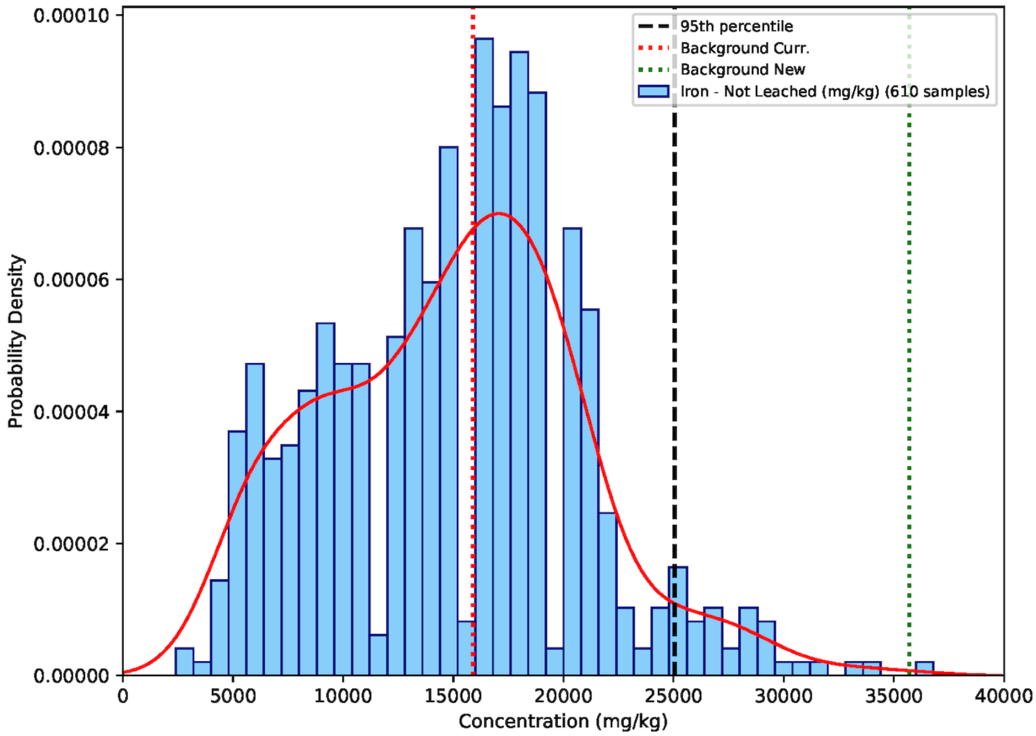

Figure 24. Histogram of RSL iron concentrations, non-REC (mg/kg).

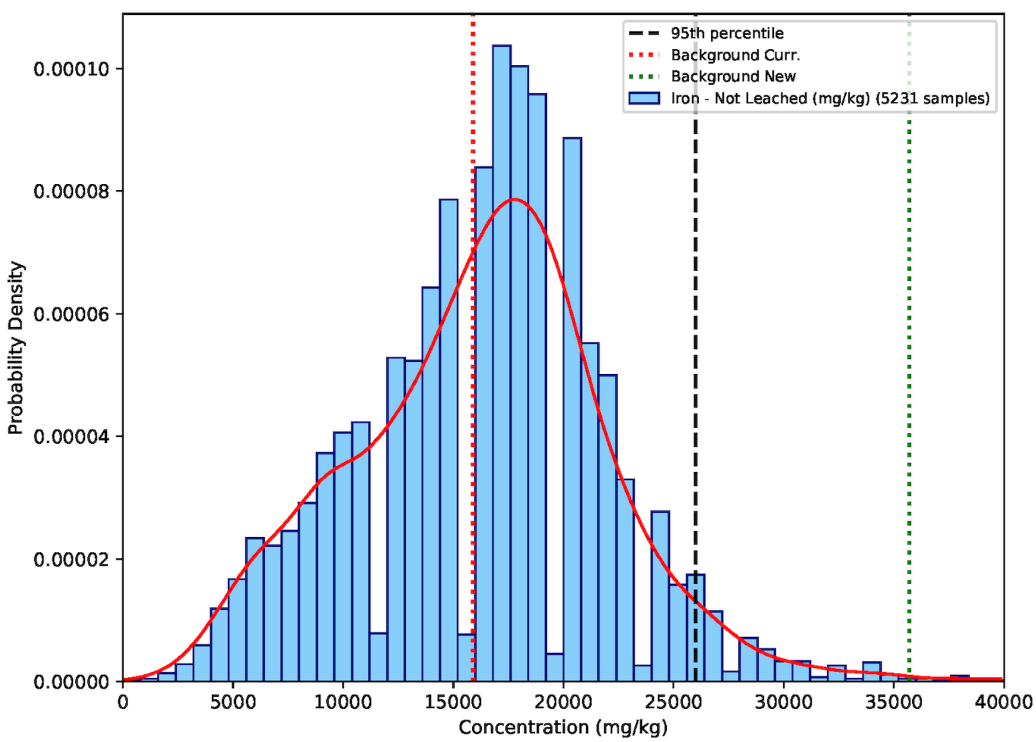

Figure 25. Histogram of RSL iron concentrations, de minimis (mg/kg).

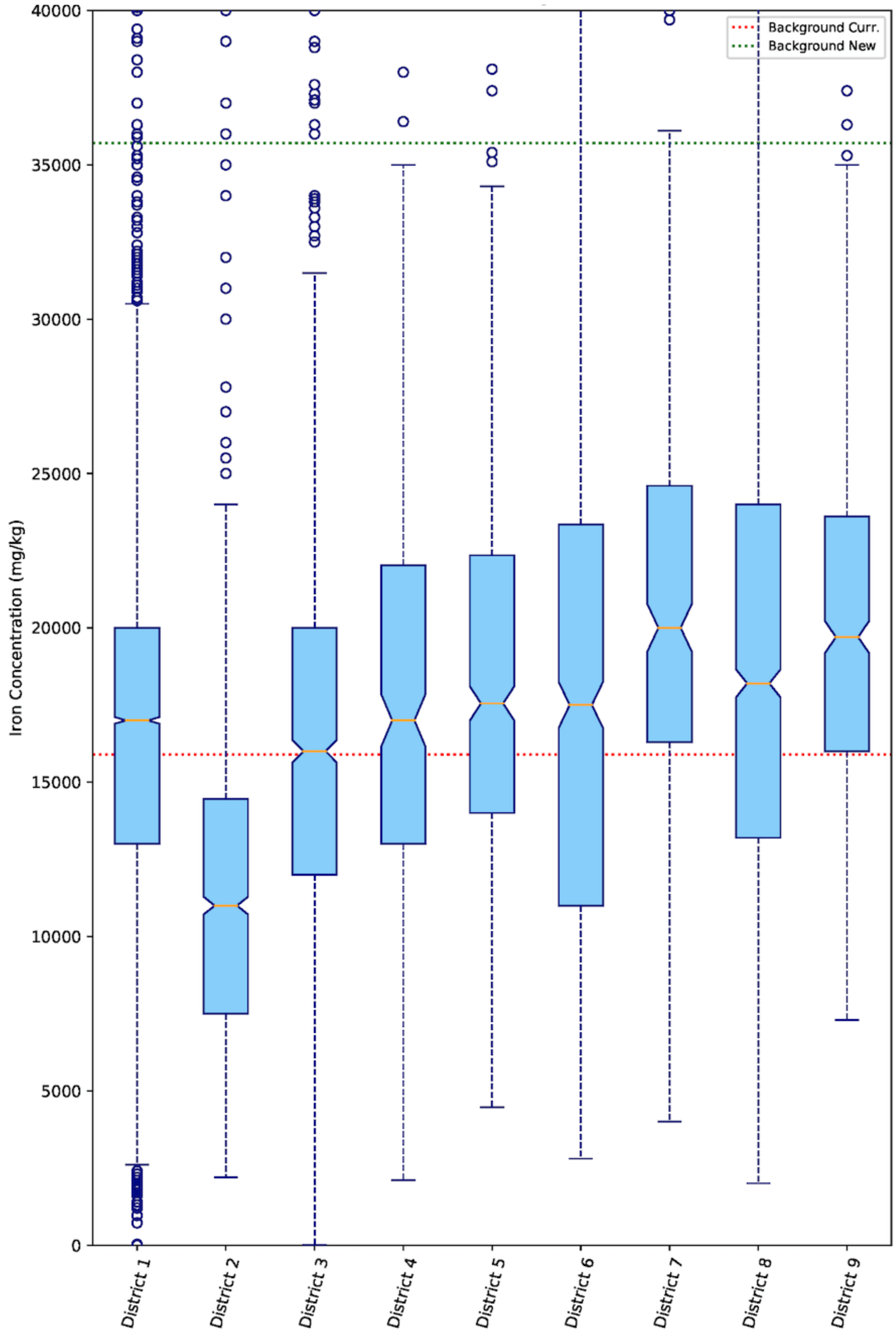

Figure 26. Boxplot of RSL iron concentrations, REC (mg/kg).

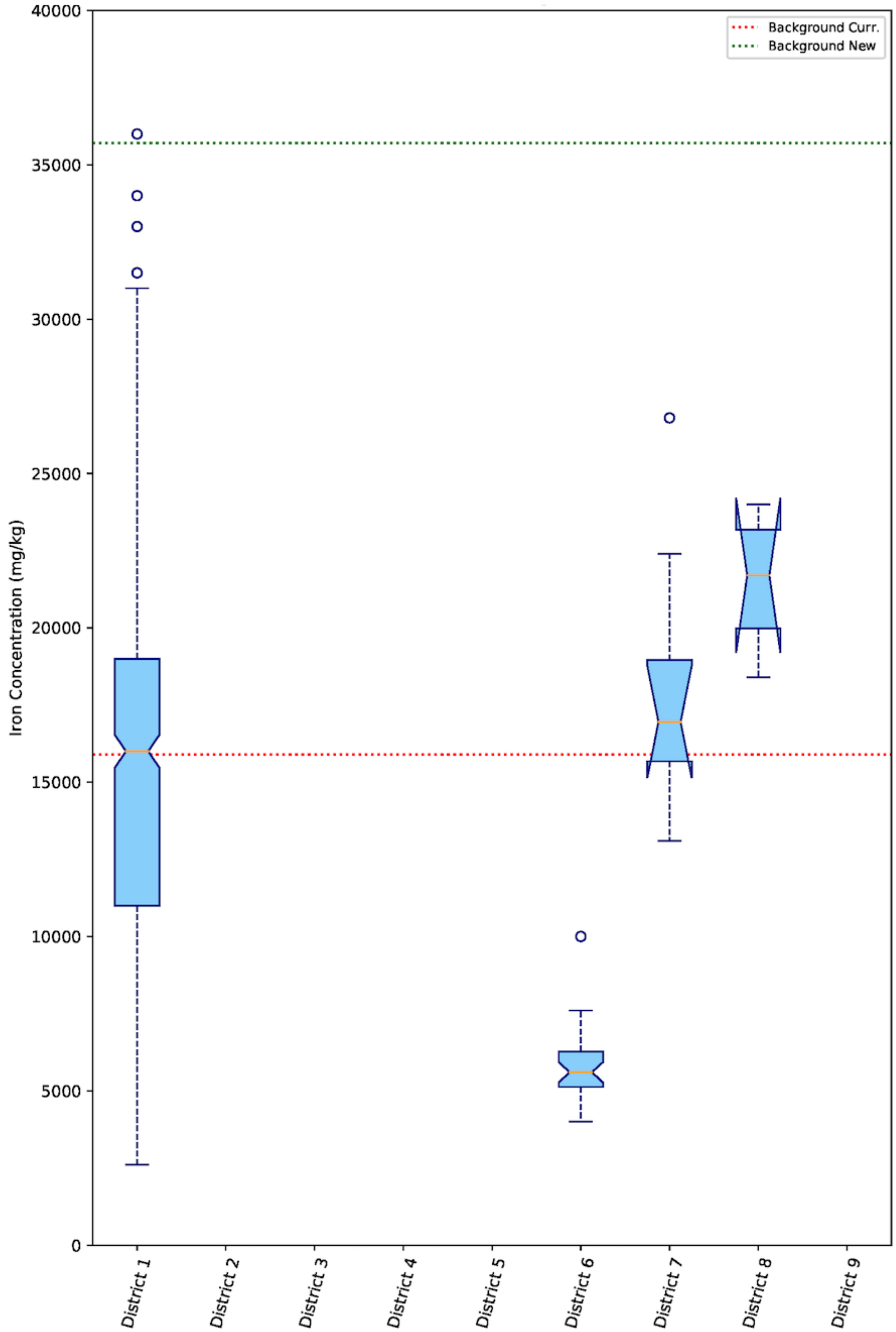

Figure 27. Boxplot of RSL iron concentrations, non-REC (mg/kg).

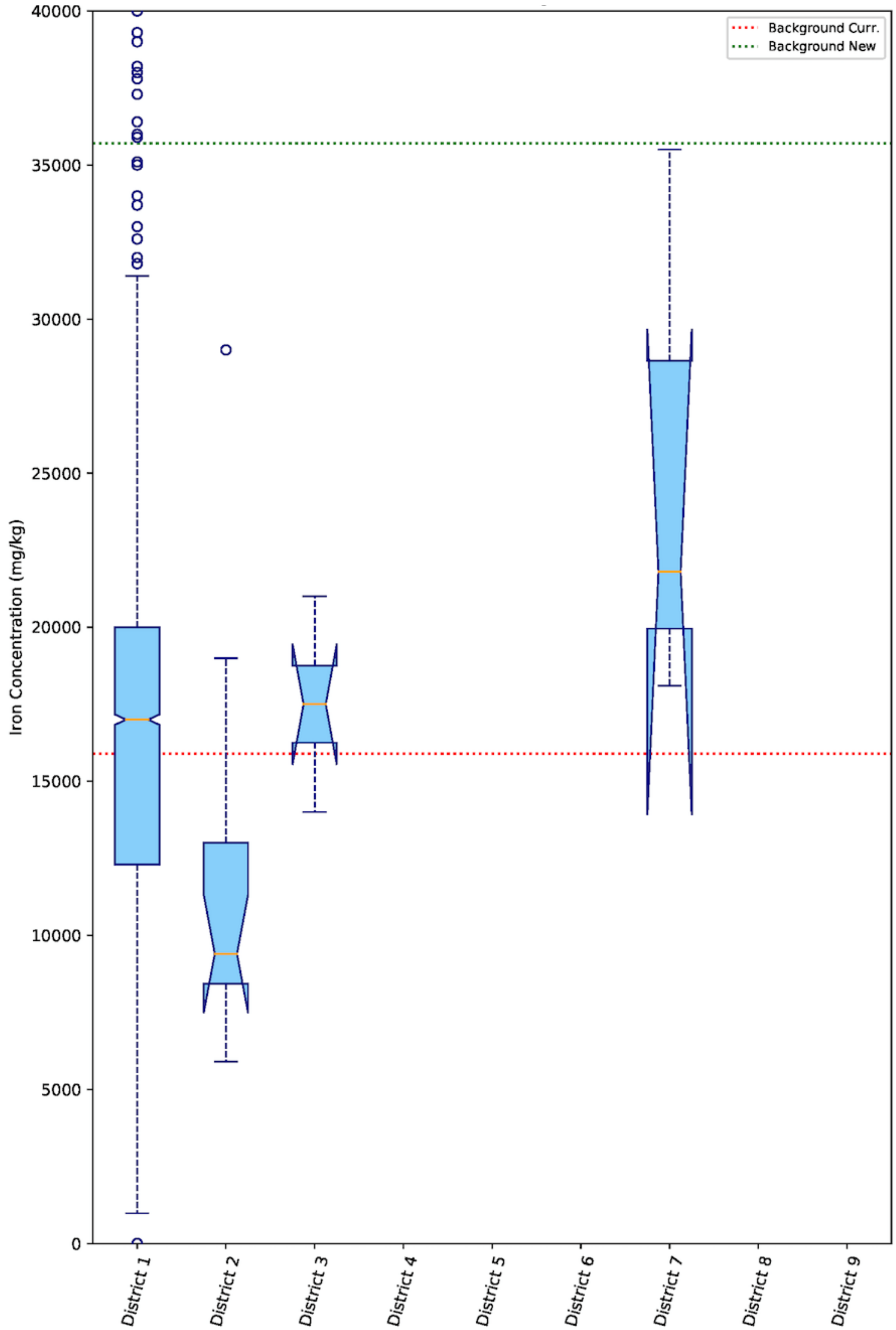

Figure 28. Boxplot of RSL iron concentrations, de minimis (mg/kg).

Lead

As shown in Table 1, the mean concentration of lead ranges from 30.42 to 48.26 mg/kg across IDOT soil contamination categories. A range of 26.1 to 49.2 mg/kg was observed for the mean among the reviewed studies of natural soils. The median for lead in the RSL database has a magnitude of 15 mg/kg. A range of 20.0 to 25.0 mg/kg was observed for the median among the reviewed studies of natural soils. The 95% confidence level for lead in the RSL database ranges from 110 to 140 mg/kg across IDOT soil contamination categories. A range of 45.1 to 50.0 mg/kg was observed for the 95% confidence level among the reviewed studies of natural soils.

As shown in Table 2, the current TACO thresholds for MSA and non-MSA counties (20.9 to 36 mg/kg) are significantly smaller than the magnitudes observed in the RSL database and similar to the range observed for natural soils. The threshold proposed by Cahill (2017) is larger than the current TACO-recommended values (45.1 mg/kg) but significantly smaller than the range of values observed in the RSL database.

Histograms of statewide concentrations in the RSL show a dominant peak between 10 and 15 mg/kg (see Figure 29 to Figure 31). Boxplots by IDOT district show moderate differences between IDOT districts (see Figure 32 to Figure 34). The histogram bin size is 5 mg/kg.

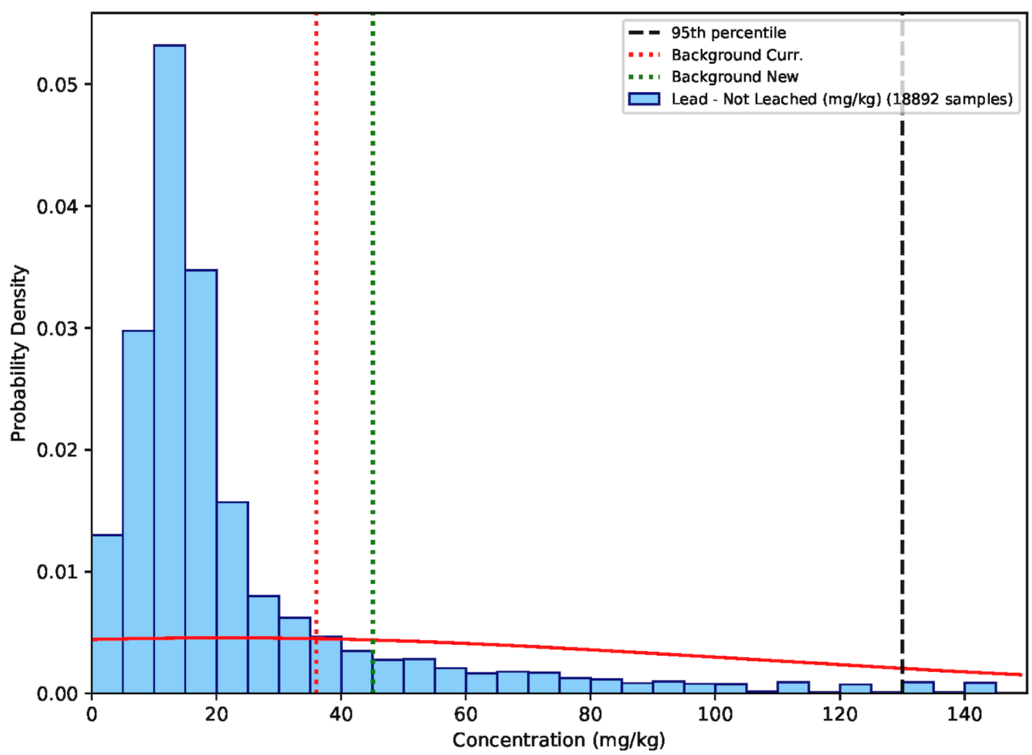

Figure 29. Histogram of RSL lead concentrations, REC (mg/kg).

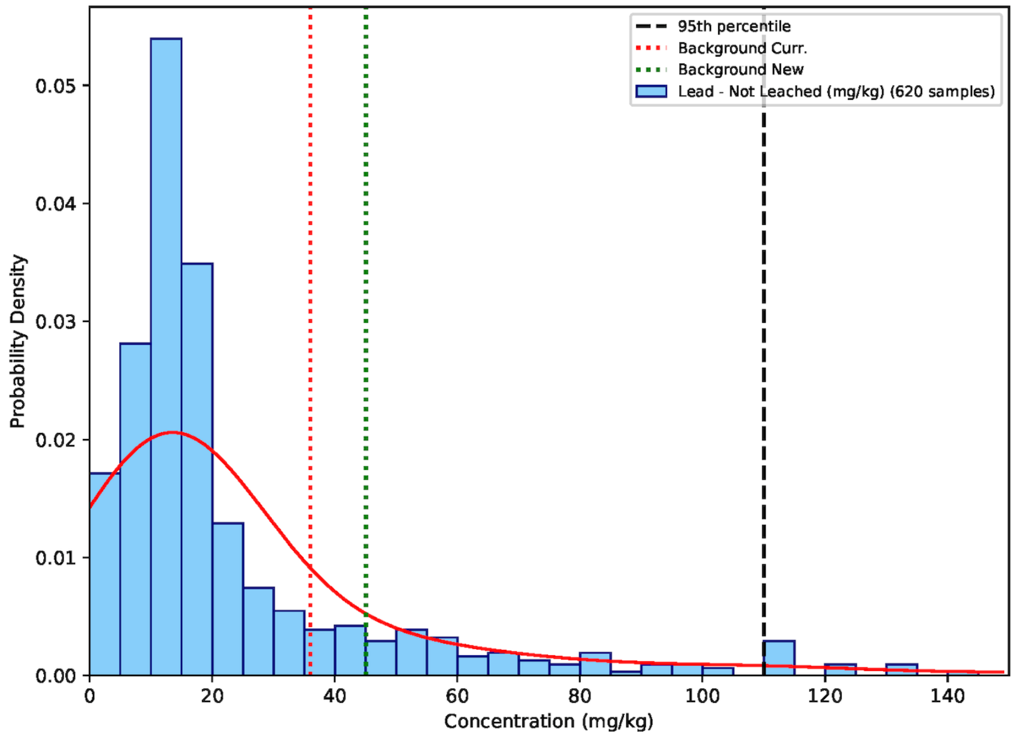

Figure 30. Histogram of RSL lead concentrations, non-REC (mg/kg).

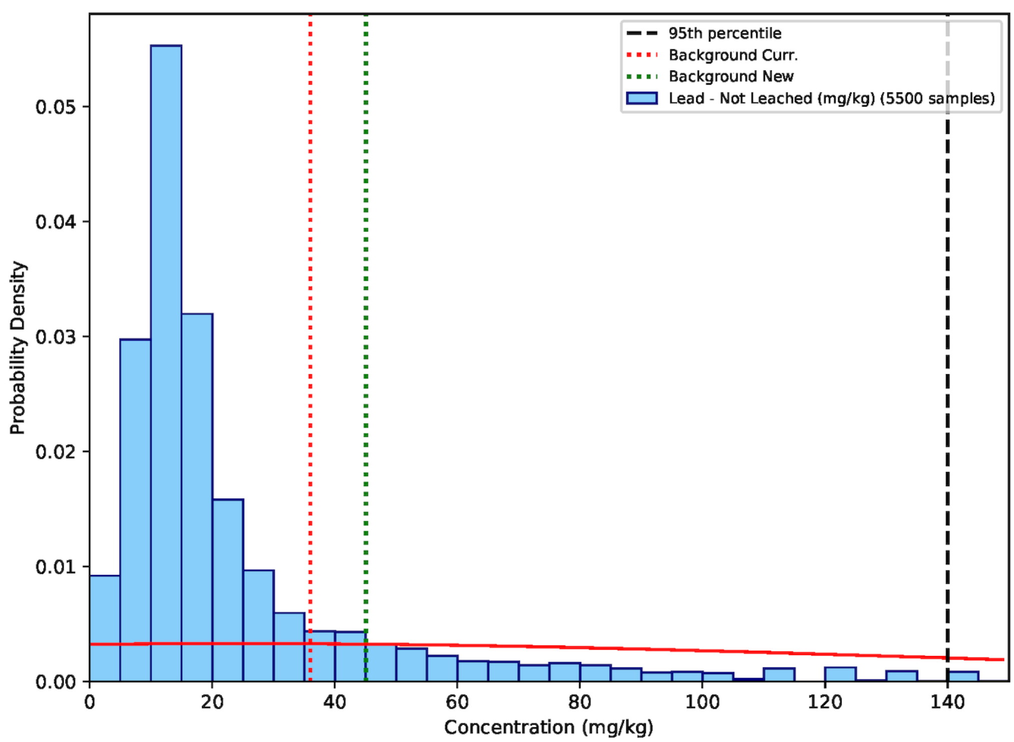

Figure 31. Histogram of RSL lead concentrations, de minimis (mg/kg).

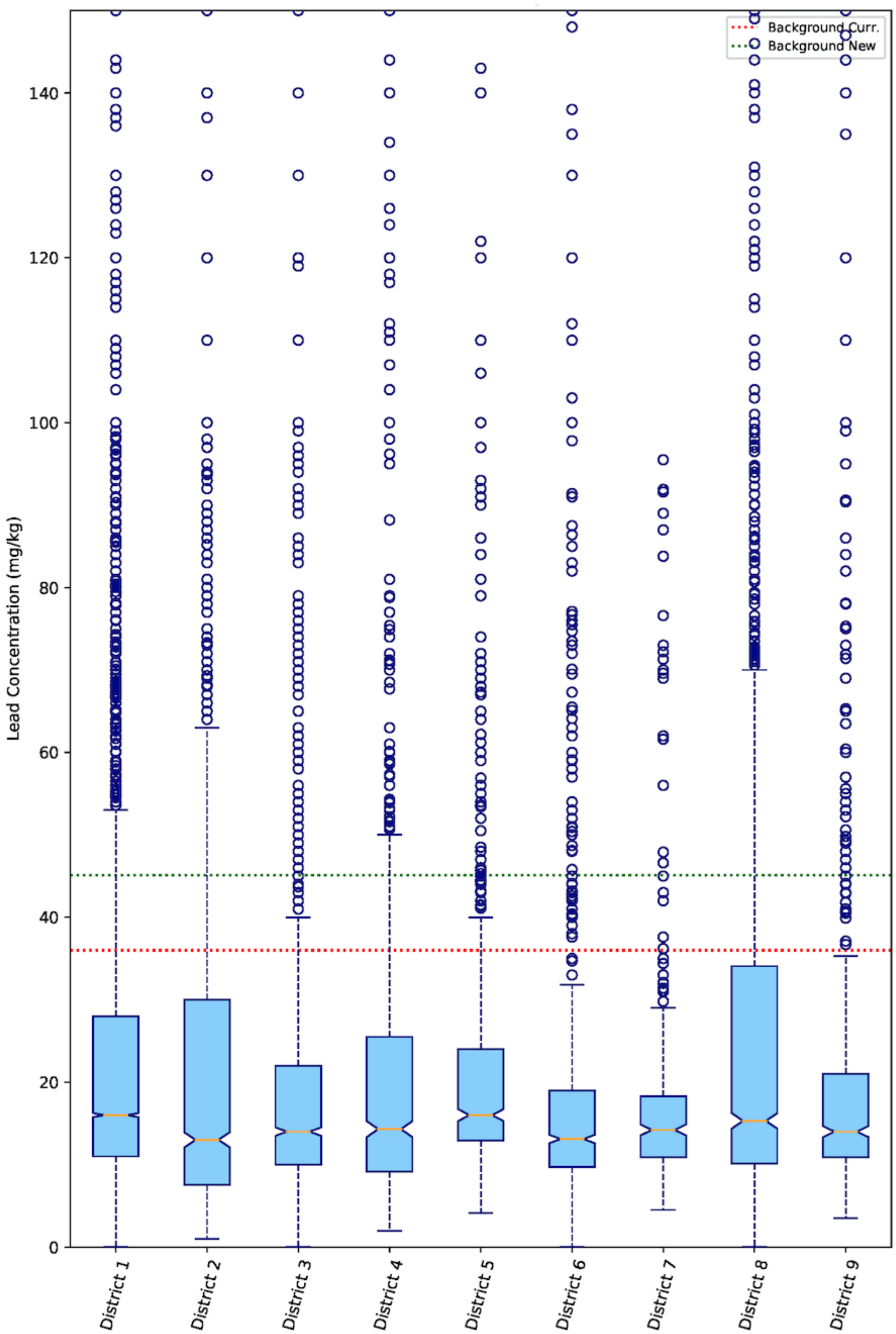

Figure 32. Boxplot of RSL lead concentrations, REC (mg/kg).

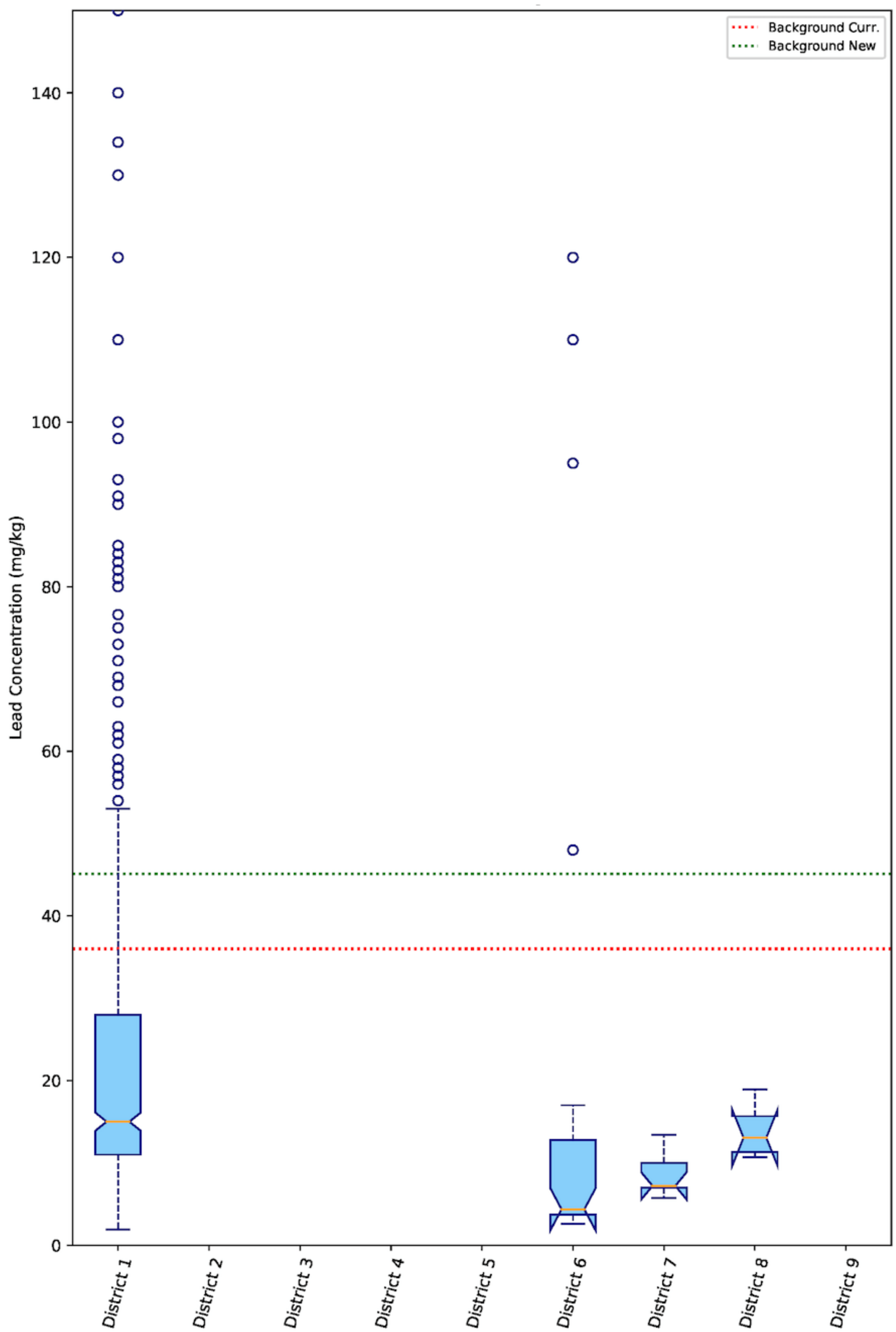

Figure 33. Boxplot of RSL lead concentrations, non-REC (mg/kg).

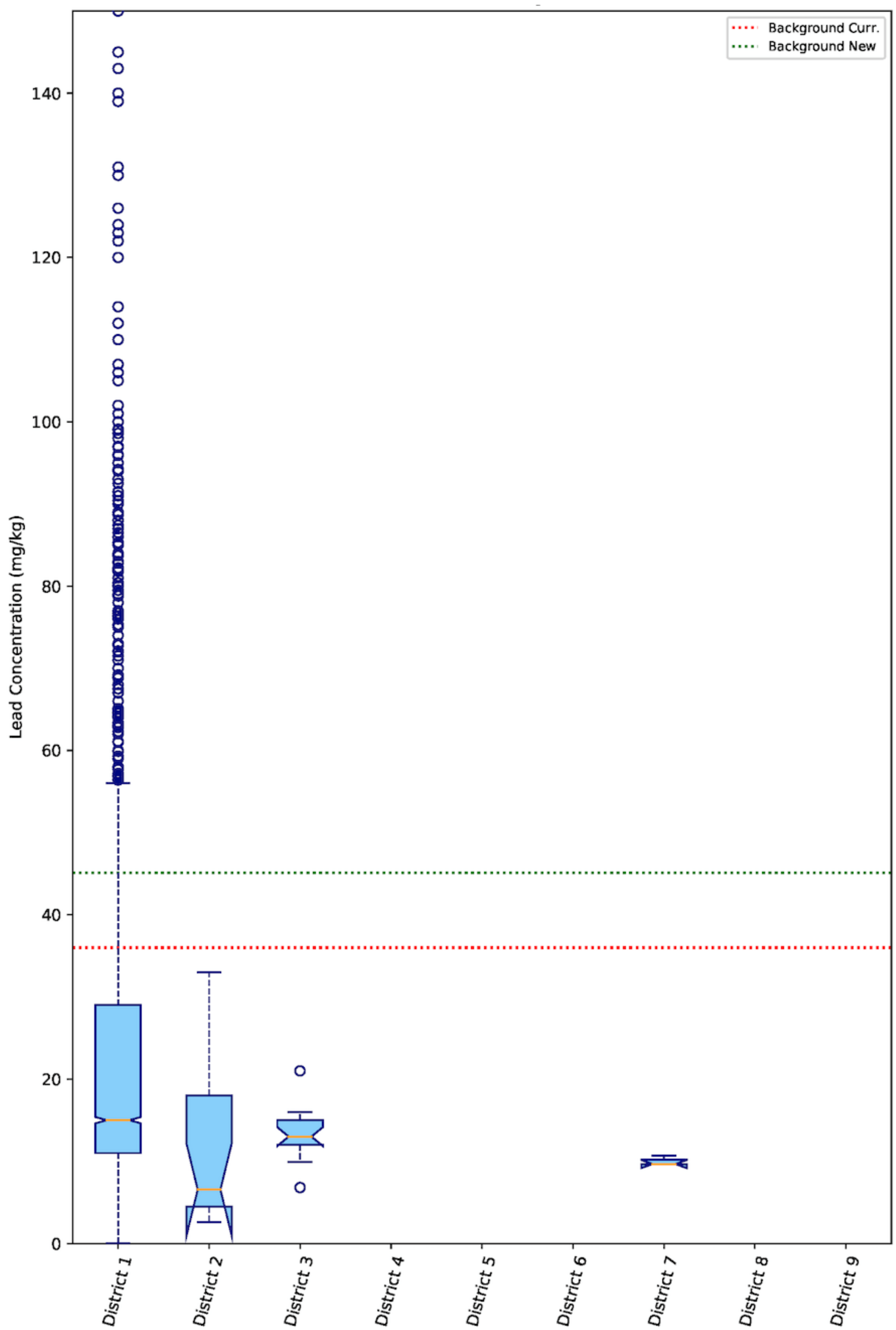

Figure 34. Boxplot of RSL lead concentrations, de minimis (mg/kg).

Manganese

As shown in Table 1, the mean concentration of manganese ranges from 444.34 to 464.78 mg/kg (0.6 wt% manganese oxide) across IDOT soil contamination categories. A range of 697 to 1,007 mg/kg (0.09 to 0.13%) was observed for the mean among the reviewed studies of natural soils. The median for manganese in the RSL database ranges from 379.50 to 386.00 mg/kg (0.5%). A range of 542 to 929 mg/kg (0.07 to 0.12%) was observed for the median among the reviewed studies of natural soils. The 95% confidence level for manganese in the RSL database ranges from 860 to 970 mg/kg (0.11 to 0.13%) across IDOT soil contamination categories. A range of 1,471 to 2,014 mg/kg (0.19 to 0.26%) was observed for the 95% confidence level among the reviewed studies of natural soils.

As shown in Table 2, the current TACO thresholds for MSA and non-MSA counties (630 to 636 mg/kg) are very small compared with the range of magnitudes observed in the RSL database and natural soils. The threshold proposed by Cahill (2017) is significantly larger than the current TACO-recommended values (1924) and in much better agreement with the 95% confidence level for the RSL database and natural soils.

Histograms of statewide concentrations in the RSL show a dominant peak between 360 and 400 mg/kg (see Figure 35 to Figure 37). Boxplots by IDOT district show moderate to significant differences between IDOT districts (see Figure 38 to Figure 40), particularly for non-REC sites. The histogram bin size is 40 mg/kg.

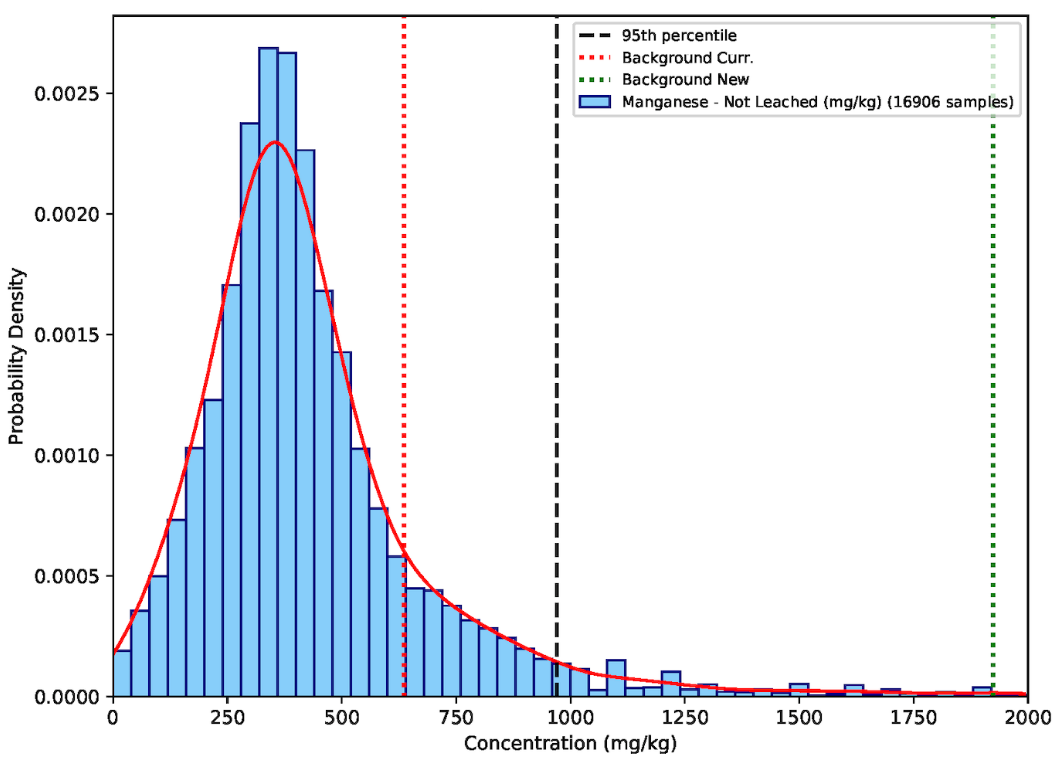

Figure 35. Histogram of RSL manganese concentrations, REC (mg/kg).

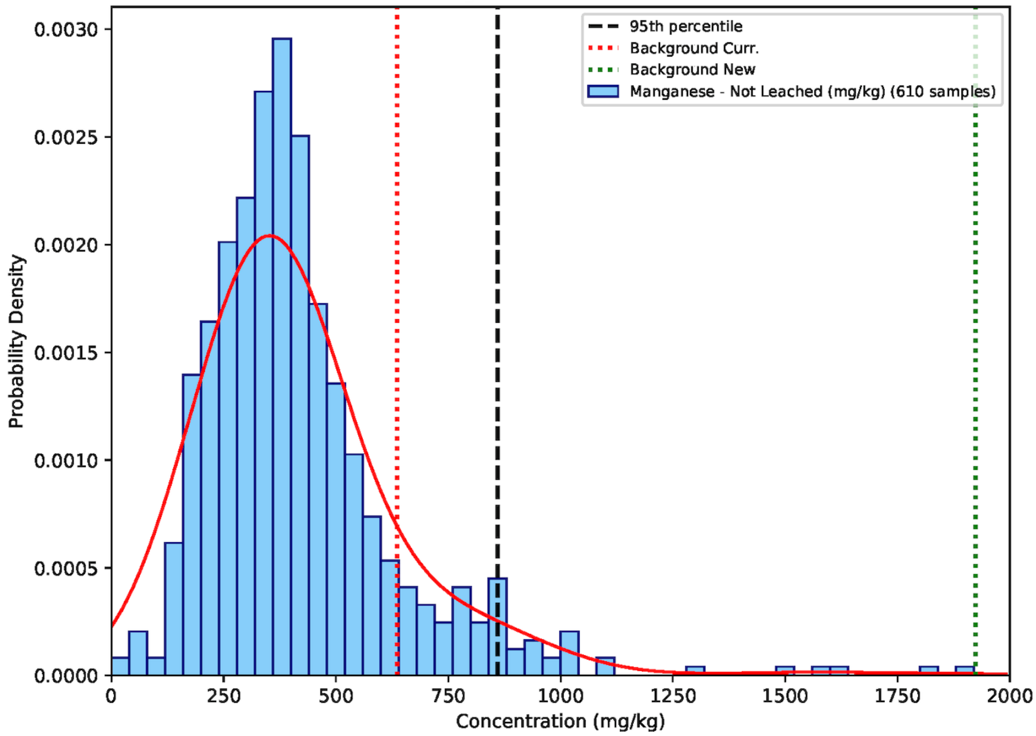

Figure 36. Histogram of RSL manganese concentrations, non-REC (mg/kg).

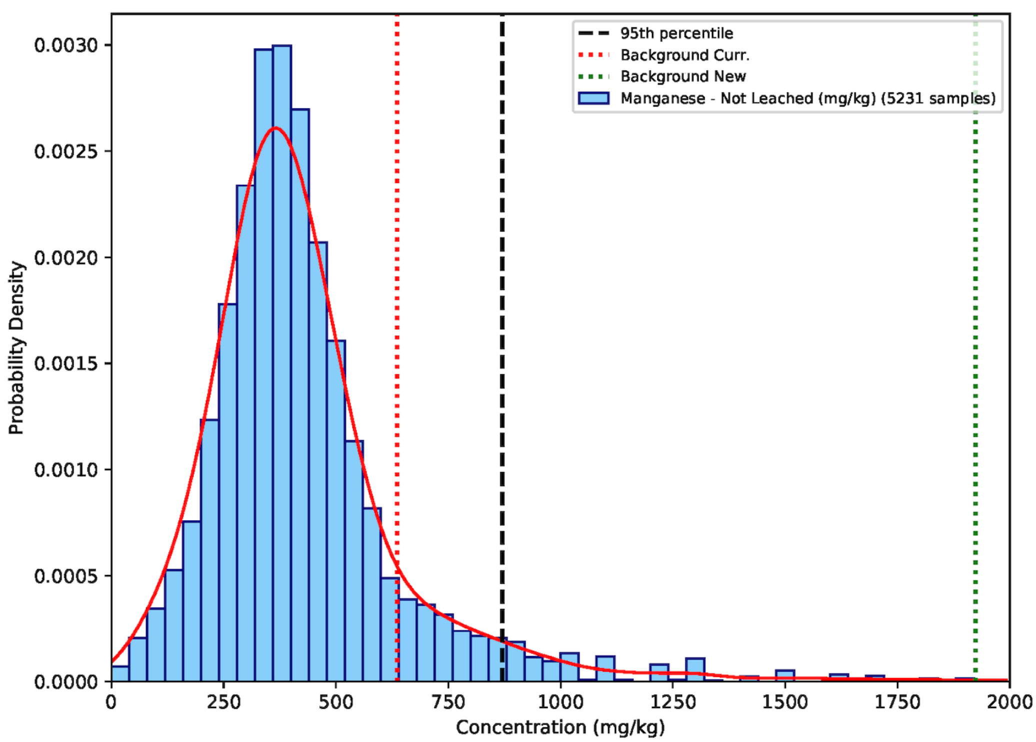

Figure 37. Histogram of RSL manganese concentrations, de minimis (mg/kg).

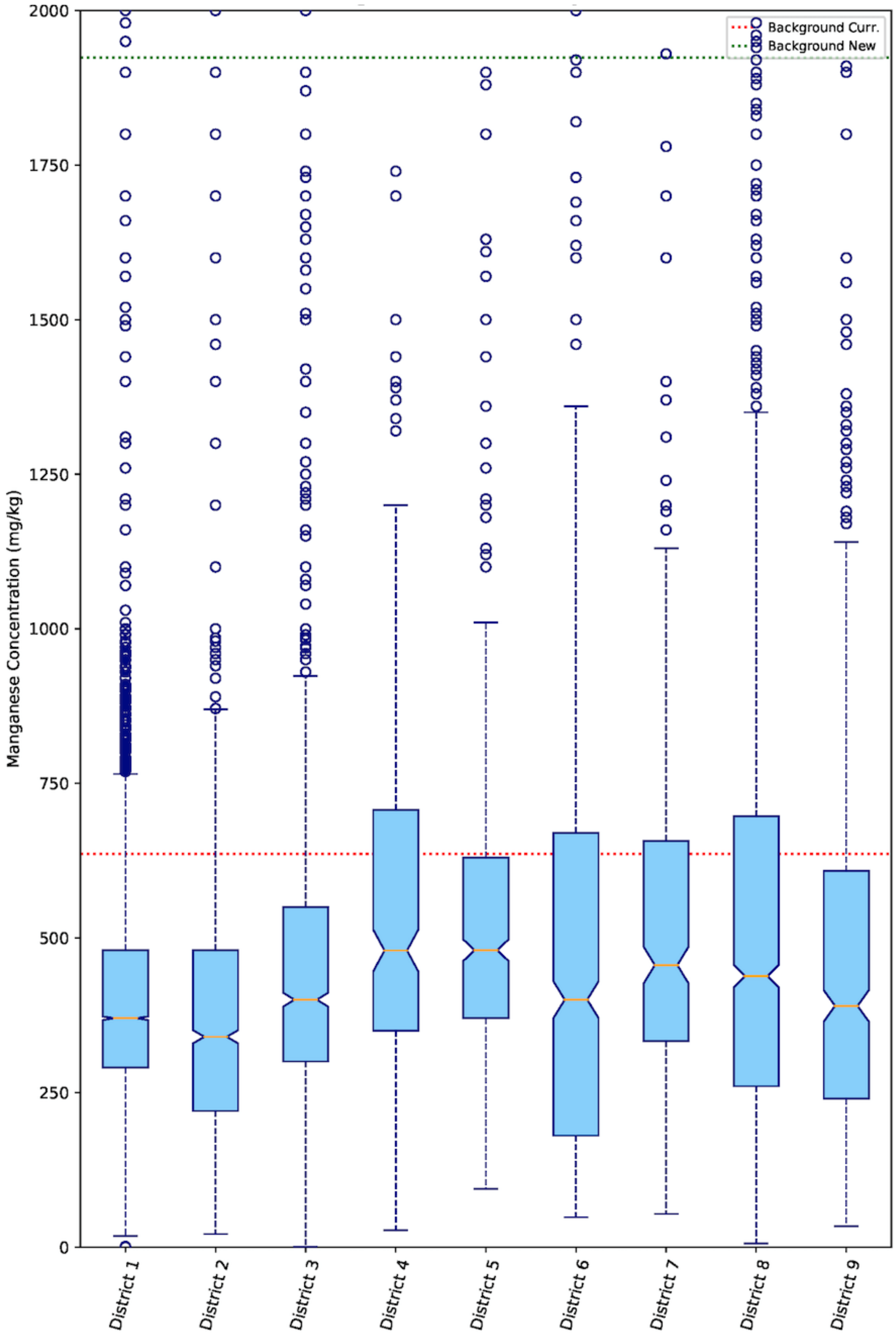

Figure 38. Boxplot of RSL manganese concentrations, REC (mg/kg).

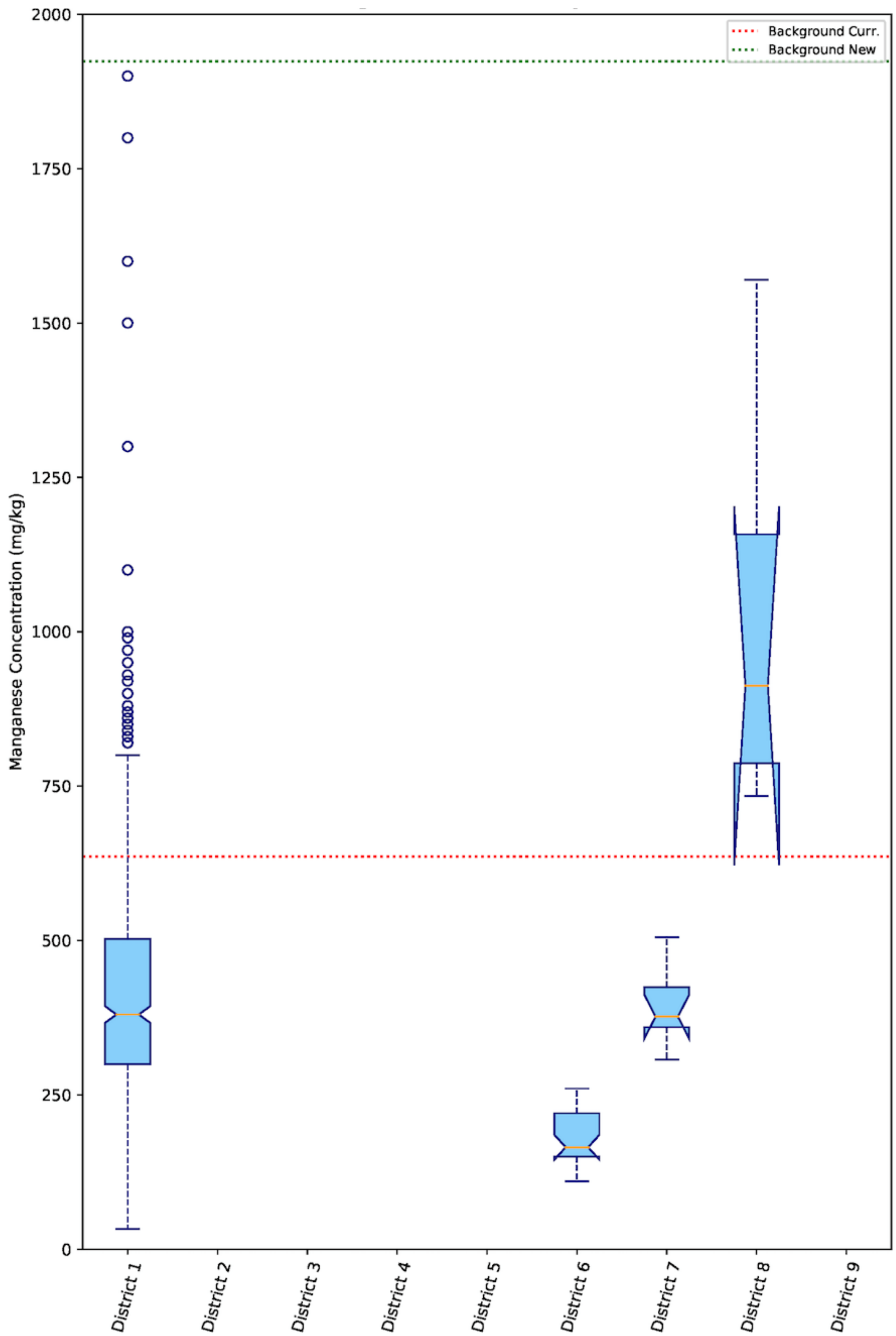

Figure 39. Boxplot of RSL manganese concentrations, non-REC (mg/kg).

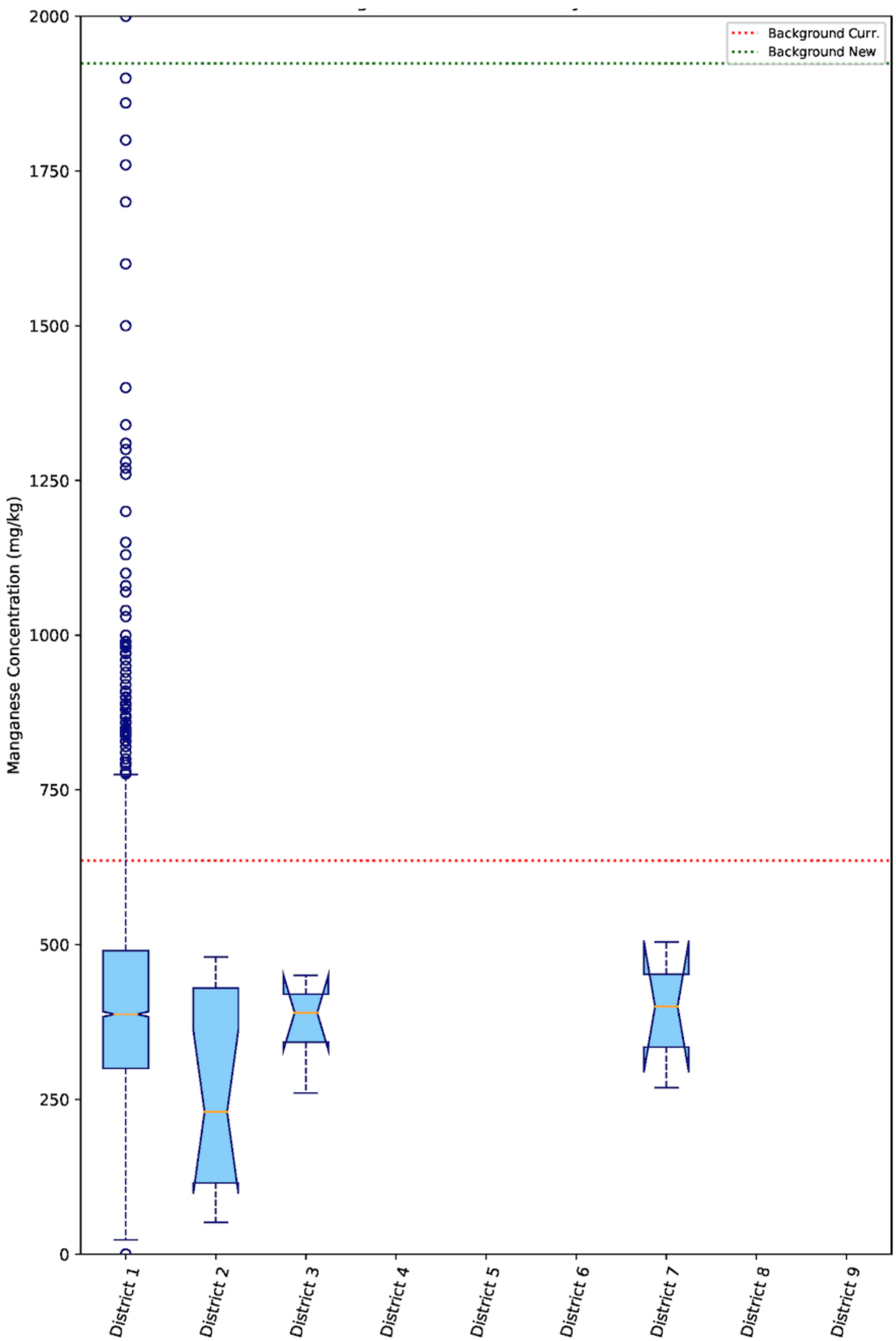

Figure 40. Boxplot of RSL manganese concentrations, de minimis (mg/kg).

CHAPTER 4: CONCLUSIONS

The 3.7-million-record IDOT Regulated Substances Library (RSL) (as of January 20, 2020) is derived from the sampling of subsurface materials (Anderson & Yacucci, 2021b). It is used to characterize site conditions encountered in rights-of-way (ROW) soils for routine preliminary site investigations in preparation for potential road construction projects. Samples in the RSL may be composed of natural soils, disturbed soils, or placed materials and may contain elevated concentrations of soil analytes if anthropogenic contamination is present. A preliminary environmental site assessment (PESA) is completed for projects in which land acquisition is required for additional ROW or easements, land is adjacent to a railroad ROW, or the land requires excavation or the location of a subsurface utility. The PESA will evaluate the history of land use and determine whether a site is a REC, is a non-REC, or has de minimis conditions. District 1 is in a predominantly urbanized setting and soil samples are collected for both REC and non-REC sites. Districts 2 through 9 soil samples are collected only for REC sites. IDOT does not assume a site is affected solely based on its identification as a REC. A site's definition as a REC indicates that releases of hazardous substances have occurred or have the potential to occur on, at, in, or adjoining the site. Sites designated as RECs are the subject of a preliminary site investigation to further evaluate site conditions for proper soil management during construction or to identify pollution point sources. This report presents a statistical analysis of RSL data, and as such, it makes no determination as to the validity of the RSL as a source of natural background soil data. Should RSL data be applied as the natural background, additional supporting justification would need to be provided, the source of which is beyond the scope of this report. The statistics from the RSL database discussed in this report are for all sample depths from 0 to 3.05 m (0 to 10 ft) for the entire state of Illinois and are classified based on the site contamination category (REC, non-REC, de minimis). Analyses for the list of 22 inorganic analytes are shown in the appendices and are further analyzed for spatial subsets (IDOT region, IDOT district, and county) (Anderson & Yacucci, 2021a).

Statistical analyses indicate general agreement between concentrations of the selected inorganic analytes listed in the RSL and those in naturally occurring soils. The thresholds proposed by Cahill (2017) for determining natural background concentrations—based on the 95% confidence level for the studies by Smith et al. (2013); Dreher and Follmer (2004a, 2004b, 2004c, 2004d, 2005); and Dreher, Follmer, and Zhang (2002, 2003a, 2003b)—show significantly better agreement with the 95% confidence level of RSL soil analyte distributions than do current thresholds (based on IEPA, 1994; tiered approach to corrective action objectives [TACO], Table G). The revised thresholds proposed by Cahill (2017) are predominantly larger than the current standards for analyte concentrations found in the TACO rules. A notable exception is antimony, for which a 70% to 75% reduction in threshold is proposed by the IEPA. The proposed threshold for antimony (Sb) is similar in magnitude to the RSL database median for many IDOT districts for the REC, non-REC, and de minimis categories and is significantly smaller than the RSL 95% confidence level. Several other RSL analytes have 95% confidence level concentrations significantly in excess of Cahill's (2017) thresholds, including Ca, Mg, Pb, and Tl. The RSL analytes at the 95% confidence level that are significantly larger than the TACO metropolitan statistical area (MSA) thresholds are Ca, Pb, Mg, Na, and Tl, and those for the TACO non-MSA are Ca, Cu, Fe, Pb, Mg, K, Se, Na, Tl, and Zn.

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